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U.S. ARMY
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— COMMITTED TO PROTECTION OF THE ENVIRONMENT —

Final Report
Technology Inventory
and Screening
(Version 3.1)

August 1988
Contract Number DAAK11-84-D0016
Task Number 28

Environmental Science And Engineering, Inc.

ROCKY MOUNTAIN ARSENAL • COMMERCE CITY, COLORADO • 80022-2180

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Rocky Mountain Arsenal

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PREPARED BY

ENVIRONMENTAL SCIENCE AND ENGINEERING, INC.

PREPARED FOR

U.S. ARMY PROGRAM MANAGER'S OFFICE FOR ROCKY MOUNTAIN ARSENAL

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THE FIRST STEP IN THE RMA FEASIBILITY STUDY IS AN INVESTIGATION OF APPLICABLE TECHNOLOGIES THAT PROVIDE A WIDE RANGE OF RESPONSE ACTIONS FOR REMEDIATION OF CONTAMINATION. THE IMPACTED MEDIA THAT WILL BE ADDRESSED ARE SOILS/SEWERS, WATER, BUILDINGS, AIR, AND BIOTA.

THIS REPORT DESCRIBES THE TECHNOLOGIES THAT WILL BE CONSIDERED FOR REMEDIATION OF THE IMPACTED MEDIA WITHIN EACH OF THE SEVEN STUDY AREAS.

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1.0 INTRODUCTION

The first step in the Rocky Mountain Arsenal (RMA) Feasibility Study (FS) is an investigation of applicable technologies that provide a wide range of response actions for remediation of contamination at RMA. The technologies should provide source and receptor control and contaminant migration management, and represent the components that are available for building comprehensive remedial alternatives for cleanup of RMA.

For the purposes of the identification of contamination and the development and implementation of remedial actions, RMA and the surrounding impacted areas are being considered as Operable Units and Study Areas. An Operable Unit is a discrete part of a remedial action that can function independently as a unit and contributes to preventing or minimizing a release or threat of release. Study Areas are geographic subareas within Operable Units that facilitate management of FS tasks by allowing the FS to proceed independently for each Study Area. The Task 28 Technology Inventory and screening effort concentrates on the Onpost Operable Unit at RMA. As shown in Figure 1.0-1, the Onpost Operable Unit consists of seven Study Areas.

Technologies and alternatives will be identified for remediation of the impacted media within each Study Area. The media to be considered are: soils/sewers, water, buildings, air, and biota. Most of the Study Areas will include each of these media, although final documentation of contaminated media will depend upon the results of the Remedial Investigations (RI) and Endangerment Assessment (EA).

Using an approach not inconsistent with relevant guidance documents from the U.S. Environmental Protection Agency (EPA), the first step in identifying applicable technologies was to compile an inventory of technologies potentially available for use at RMA. Information was drawn from a number of sources, and technology descriptions were developed as described in Section 2.0. This master list was then screened using a two-step process in order to develop a list of applicable technologies for each Study Area.

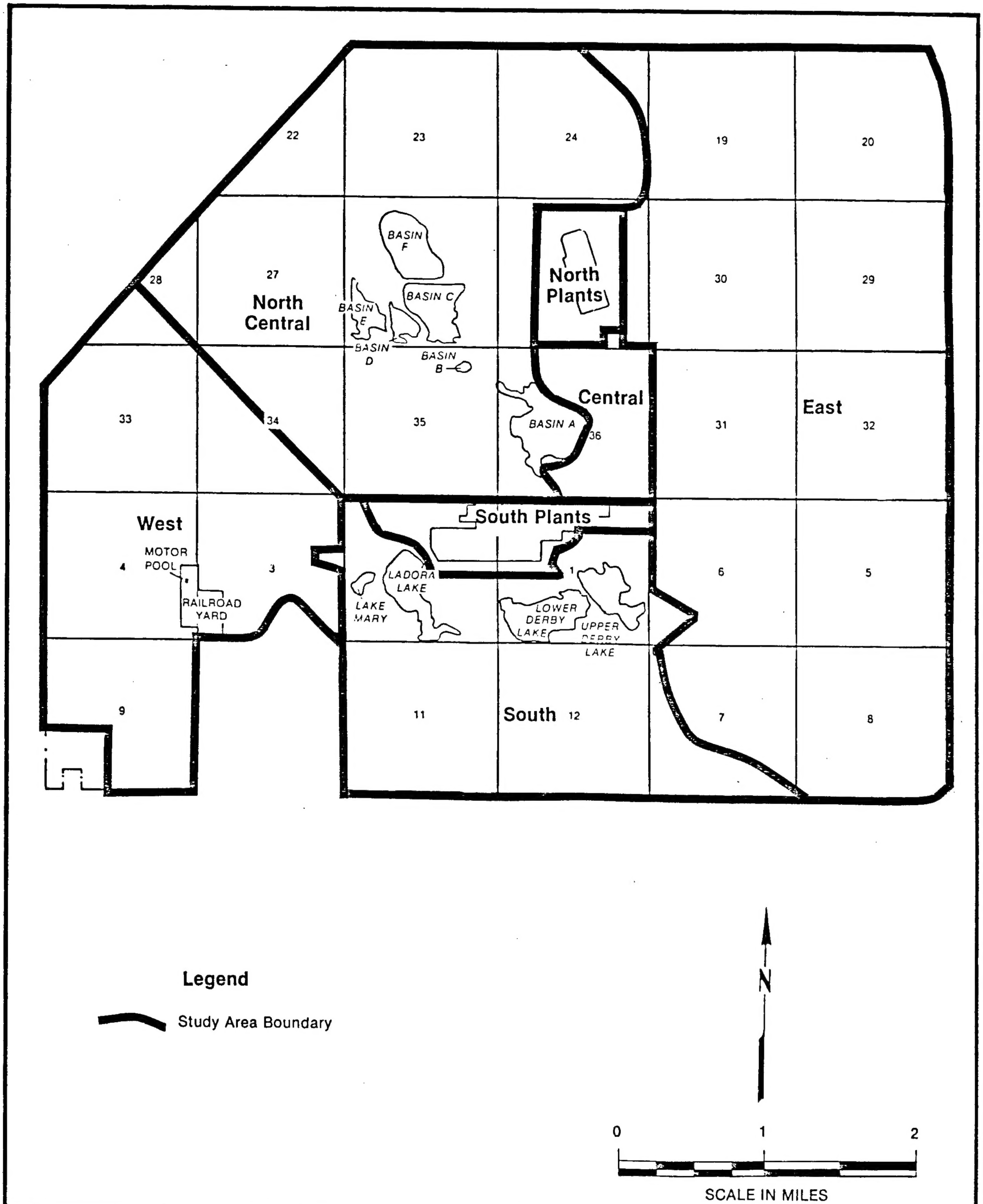

Figure 1.0-1
ONPOST OPERABLE UNITS AND STUDY AREAS

SOURCE: ESE, 1988

Prepared for:
U.S. Army Program Manager's Office For Rocky Mountain Arsenal
Aberdeen Proving Ground, Maryland

Technology screening was first performed on an arsenal-wide basis and then a separate technology screening was performed for each Study Area. The latter screening step rejected technologies which were not applicable to conditions within the subject area. Screening criteria encompassed site characteristics, material/contaminant characteristics, and technological limitations. Justifications for rejection, based on these criteria, are described in Section 3.0.

Preliminary and interim guidance documents issued pursuant to the Superfund Amendments and Reauthorization Act of 1986 (SARA) set forth the regulatory position on relative desirability of certain technologies being included in remedial action alternatives. The guidance establishes a preference for remedial actions which employ technologies that permanently and significantly reduce the volume, toxicity, or mobility of hazardous substances. It also gives special consideration to incorporating "innovative" technologies if there is reasonable belief they may offer a better solution to a given problem than other available options. Some reevaluation of specific technologies may be required at a later date as newer technologies may be available by the time remedial actions at RMA are initiated.

2.0 TECHNOLOGY INVENTORY

Five distinct media which may be contaminated at RMA were identified and include: soils/sewers, water, buildings, air, and biota. Although not all of these media may be contaminated within each Study Area, they are considered in each Study Area until RI and EA studies indicate that the media is not significant within a Study Area.

Seven response actions were evaluated for each contaminated medium and include:

- Removal - Refers to extraction and transfer of contaminated and uncontaminated materials from a site. Removal may include demolition, excavation, dredging, pumping and materials transport. Materials may be removed from their existing location, and may be removed from the site or removed to another location on the site;
- Disposal - Includes the group of technologies that involve the final disposition of waste material in facilities with varying degrees of secureness. That is, hazardous materials may be disposed of in secure landfills where as nonhazardous wastes may be disposed of in municipal landfills. Other disposal techniques may include deep well injection or above ground discharge of uncontaminated soils, waters or other clean materials. The materials to be disposed of may or may not be treated;
- Storage - The holding of materials for a temporary period after which the materials are treated, disposed, or stored elsewhere. Hazardous waste can be stored and contained in tanks, surface impoundments or drums, or other acceptable containers. A container is any portable device in which a material is stored, transported, treated, or disposed;
- Direct Treatment - Involves methods applicable for treating liquid, solid, and vapor waste streams. Many of the methods are widely used in industrial waste treatment applications. Waste streams resulting from the cleanup of hazardous waste sites vary widely with respect to volume, physical condition, and type of contaminants. Because waste streams are so diverse, a variety of treatment technologies may have potential application to hazardous

waste site cleanup. Rarely will any one unit technology be sufficient for waste treatment. Therefore, unit treatment technologies are frequently used in combination, and may in some cases involve pretreatment technologies;

- In-situ Treatment - Entails methods for chemical, biological, or physical manipulations which degrade, remove, or immobilize contaminants; methods for delivering solutions to the subsurface; and methods for controlling the spread of contaminants and treatment reagents beyond the treatment zone. In-situ treatment technologies are generally not as developed as other currently available remedial technologies for restoring contaminated aquifers. However, some in-situ treatment technologies have demonstrated success in actual site remediations. In addition, most of the methods are based on standard waste treatment technologies and are conceptually applicable as in-situ treatment methods. Applicability of in-situ methods must generally be determined on a site-specific basis by treatability testing;
- Containment - Refers to technologies which isolate contaminated materials from clean materials. The purpose of containment is to segregate hazardous constituents from clean materials in order to minimize migration and spread of contaminants. Such technologies as subsurface barriers may be used to stop ground water flow into a zone of hazardous materials or may be used to contain the flow of contaminated ground water from a zone of hazardous materials; and
- Reclamation - The action by which areas are returned to their original state prior to contamination and remediation, or are returned to an effectively equivalent state. Reclamation may involve restoration of land, water and biota so that following remediation, the site has been stabilized in order to minimize further deterioration of the environment.

Technologies were identified and are listed by appropriate media and response action as shown in Table 2.0-1. Resources used in identifying technologies included Army reports; the RMA Information Center Catalog;

government publications; other published references in the open literature; project experience; vendor communications; and correspondence from other interested parties. Each technology was described in sufficient detail for evaluation during the technology screening process (Appendix A).

The available technologies that are given in Table 2.0-1 are for use in performing a particular response action in the subject media. Additionally, available technologies that are considered "innovative" are listed in Table 2.0-2. They are given special consideration, in view of the possibility that emerging technologies may ultimately offer better solutions to certain remediation problems.

TABLE 2.0-1. AVAILABLE TECHNOLOGIES AND PROCESSES

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	PROCESSES
SOILS/SEWERS (INCLUDES SEDIMENTS AND PIPING)	REMOVAL	1. Demolition	
		2. Excavation	
		3. Dredging	a. Mechanical b. Hydraulic c. Pneumatic
		4. Pumping	
		5. Materials Transport	
	DISPOSAL	1. Landfilling	a. Onsite Secure b. Offsite Secure c. Onsite Industrial d. Offsite Industrial e. Onsite Municipal f. Offsite Municipal g. Backfill
		2. Deep Well Injection	a. Onsite b. Offsite
		3. Above Ground Discharge	
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	
		2. Stockpile/Waste Pile	
		3. Surface Impoundment	
		4. Drums/Containers/Tanks	
	DIRECT TREATMENT	Physical/Chemical Treatment	
		1. Washing	
		2. Solidification and Stabilization	a. Sorption b. Lime-Fly Ash Pozzolan Process c. Pozzolan-Portland Cement Process d. Thermoplastic Microencapsulation e. Macroencapsulation f. Glassification g. Down Draft Sintering
		3. Volatilization (Natural)	
		4. Magnetic Separation	
		5. Dewatering	a. Centrifuge b. Gravity Thickening c. Belt Press d. Plate and Frame e. Drying Bed f. Vacuum Filtration
		6. Neutralization	
		7. Hydrolysis	
		8. Ultraviolet Photolysis	

MEDIA	RESPONSE ACTION	TECHNOLOGIES	PROCESSES
SOILS/SEWERS (INCLUDES SEDIMENTS AND PIPING)	DIRECT TREATMENT	Physical/Chemical Treatment	
		9. Electron Beam	
		10. Gamma Irradiation	
		Biological Treatment	
		1. Aerobic	a. Composting
			b. Land Application
			c. Land Farming
			d. Bio-Uptake
			e. Bioreactor
			f. Enzymatic Degradation
			g. Waste Stabilization Pond/Lagoon
		2. Anaerobic	
		Thermal Treatment	
		1. Cryogenics	
		2. Evaporation	a. Solar
			b. Enhanced
			c. Spray Dryer (Flash Drying)
		3. Thermal Desorption/Volatilization	a. Indirect Heating
			b. Radio-Frequency Heating
			c. Microwave Heating
			d. Steam Injection
		4. Surface Flashing/Flaming	
		5. Open Burning	
		6. CO2 Laser	
		7. Thermal Oxidation/Incineration	a. Rotary Hearth
			b. Multiple-Hearth
			c. Fluidized-Bed/Circulating-Bed
			d. Rotary Kiln
			e. Industrial Kiln
			f. Infrared Electric Furnace
			g. Pyrolysis/Electric Heater
			h. Submerged Quench Liquid Incineration
			i. Transportable Thermal Treatment Unit (TTTU)
			j. Low-Temperature Thermal Decomposition
			k. Wet Air Oxidation
			l. High-Temperature Fluid Wall (HTFW)
			m. Molten Salt/Sodium Fluxing
			n. Molten Glass
			o. Hot Plasma
			p. Supercritical Water Oxidation

TABLE 2.0-1. AVAILABLE TECHNOLOGIES AND PROCESSES

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	PROCESSES
SOILS/SEWERS (INCLUDES SEDIMENTS	IN-SITU TREATMENT	Physical/Chemical Treatment	
		1. Solidification and Stabilization	a. Sorption b. Lime-Fly Ash Pozzolan Process c. Pozzolan-Portland Cement Process d. Thermoplastic Microencapsulation e. Macroencapsulation f. Vitrification g. Polymerization
		2. Vacuum Extraction 3. Flushing 4. Venting 5. Chelation	
		Biological Treatment	
		1. Aerobic	a. Land Farming b. Bio-Uptake c. Biodegradation d. Enzymatic Degradation
		2. Anaerobic	
		Thermal Treatment	
		1. Cryogenics 2. Evaporation	a. Solar b. Enhanced
		3. Thermal Desorption/Volatilization	a. Indirect Heating b. Radio-Frequency Heating c. Microwave Heating d. Steam Injection
		4. CO2 Laser	
	CONTAINMENT	1. Subsurface Barriers	a. Slurry Wall b. Grout Curtain c. Sheet Piling d. Bottom Sealing e. Pneumatic Barrier f. Synthetic Membrane Cut Off Wall g. Dynamic Deep Compaction h. Hydraulic Controls
		2. Subsurface Drains	a. French b. Tile c. Dual Media d. Trench/Gallery

TABLE 2.0-1. AVAILABLE TECHNOLOGIES AND PROCESSES

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	PROCESSES
SOILS/SEWERS (INCLUDES SEDIMENTS AND PIPIING)	CONTAINMENT	3. Capping	a. Singled-Layered Soil b. Multimedia c. Clay d. Synthetic Membrane Liner e. Surface Sealing f. Thermoplastic
		4. Diversion	a. Dikes and Berms b. Ditches and Trenches c. Terraces and Benches d. Culverts e. Levees and Floodwalls f. Cofferdams g. Grading and Revegetation h. Channels and Waterways
	RECLAMATION	1. Site Rehabilitation	a. Backfilling/Regrading b. Stabilization
		2. Grouting/Relining	
WATER	REMOVAL	1. Pumping	a. Well Points b. Extraction/Injection Wells
		2. Materials Transport	
	DISPOSAL	1. Deep Well Injection	a. Onsite b. Offsite
		2. Above Ground Discharge	a. Publicly Owned Treatment Works (POTWs) b. Surface Streams c. Infiltration Basins
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS) 2. Surface Impoundment 3. Drums/Containers/Tanks	
	DIRECT TREATMENT	Physical/Chemical Treatment	
		1. Solidification and Stabilization	a. Sorption b. Lime-Fly Ash Pozzolan Process c. Pozzolan-Portland Cement Process

TABLE 2.0-1. AVAILABLE TECHNOLOGIES AND PROCESSES

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	PROCESSES
WATER	DIRECT TREATMENT	Physical/Chemical Treatment	
		1. Solidification and Stabilization	d. Thermoplastic Microencapsulation e. Polymerization
		2. Absorption	
		3. Magnetic Separation	
		4. Sedimentation	
		5. Flotation/Separation	
		6. Filtration/Separation	a. Reverse Osmosis b. Filtration c. Ultra-Filtration
		7. Dialysis	
		8. Electrodialysis	
		9. Solvent Extraction	
		10. Stripping	a. Air b. Steam
		11. Steam Distillation	
		12. Adsorption	a. Activated Carbon b. Activated Alumina c. Ion Exchange and Sorption Resins
		13. Neutralization	
		14. Precipitation/Flocculation	
		15. Chelation	
		16. Hydrolysis	
		17. Oxidation/Reduction	a. Chemical b. Electrolytic c. Ultraviolet-Ozone Treatment
		18. Chemical Dehalogenation	a. Alkali Metal b. Alkali Metal and Polyethylene Glycol (A/PEG)
		19. Ultraviolet Photolysis	
		20. Electron Beam	
		21. Gamma Irradiation	
		Biological Treatment	
		1. Aerobic	a. Land Application b. Bio-Uptake c. Bioreactor d. Enzymatic Degradation e. Waste Stabilization Pond/Lagoon f. Activated Sludge g. Powdered Activated Carbon Treatment (PACT) h. Sequence Batch Reactor (SBR)

MEDIA	RESPONSE ACTION	TECHNOLOGIES	PROCESSES
WATER	DIRECT TREATMENT	Biological Treatment	
		1. Aerobic	i. Trickling Filter/Fixed Film j. Biological Tower k. Publicly Owned Treatment Work (POTW)
		2. Anaerobic	
		Thermal Treatment	
		1. Evaporation	a. Solar b. Enhanced
		2. Thermal Desorption/Volatilization	a. Indirect Heating b. Radio-Frequency Heating c. Microwave Heating d. Steam Injection
		3. Thermal Oxidation/Incineration	a. Rotary Hearth b. Multiple-Hearth c. Fluidized-Bed/Circulating-Bed d. Rotary Kiln e. Industrial Kiln f. Infrared Electric Furnace g. Pyrolysis/Electric Heater h. Submerged Quench Liquid Incineration i. Transportable Thermal Treatment Unit (TTTU) j. Low-Temperature Thermal Decomposition k. Wet Air Oxidation l. High-Temperature Fluid Wall (HTFW) m. Molten Salt/Sodium Fluxing n. Molten Glass o. Hot Plasma p. Supercritical Water Oxidation
	IN-SITU TREATMENT	Physical/Chemical Treatment	
		1. Solidification and Stabilization	a. Polymerization
		2. Adsorption	a. Permeable Treatment Bed
		3. Neutralization 4. Precipitation/Flocculation 5. Chelation	

TABLE 2.0-1. AVAILABLE TECHNOLOGIES AND PROCESSES

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	PROCESSES
WATER	IN-SITU TREATMENT	Physical/Chemical Treatment	
		6. Hydrolysis	
		7. Oxidation/Reduction	a. Chemical b. Electrolytic
		Biological Treatment	
		1. Aerobic	a. Bio-Uptake b. Biodegradation c. Enzymatic Degradation
		2. Anaerobic	
		Thermal Treatment	
		1. Evaporation	a. Solar b. Enhanced
		2. Thermal Desorption/Volatilization	a. Indirect Heating b. Radio-Frequency Heating c. Microwave Heating d. Steam Injection
	CONTAINMENT	1. Subsurface Barriers	a. Slurry Wall b. Grout Curtain c. Sheet Piling d. Bottom Sealing e. Pneumatic Barrier f. Synthetic Membrane Cut Off Wall g. Dynamic Deep Compaction h. Hydraulic Controls
		2. Subsurface Drains	a. French b. Tile c. Dual Media d. Trench/Gallery
		3. Capping	a. Synthetic Membrane Liner
		4. Diversion	a. Dikes and Berms b. Ditches and Trenches c. Terraces and Benches d. Culverts f. Levees and Floodwalls g. Cofferdams h. Grading and Revegetation i. Channels and Waterways

TABLE 2.0-1. AVAILABLE TECHNOLOGIES AND PROCESSES

MEDIA	RESPONSE ACTION	TECHNOLOGIES	PROCESSES
WATER	RECLAMATION	1. Site Rehabilitation	a. Recharge
BUILDINGS (INCLUDES PROCESS PIPING AND TANKS)	REMOVAL	1. Demolition	a. Crushing and Sorting
		2. Excavation 3. Materials Transport	
	DISPOSAL	1. Landfilling	a. Onsite Secure b. Offsite Secure c. Onsite Industrial d. Offsite Industrial e. Onsite Municipal f. Offsite Municipal
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS) 2. Stockpile/Waste Pile 3. Drums/Containers/Tanks	
	DIRECT TREATMENT	Physical/Chemical Treatment 1. Washing 2. Vacuum Dusting 3. Hydraulic Scour 4. Mechanical Scour 5. Acid Etch 6. Drill/Spall 7. Scarification 8. Steam Cleaning 9. Sealant/Enclosure 10. Electropolishing 11. Ultrasound 12. Solidification and Stabilization	a. Lime-Fly Ash Pozzolan Process b. Pozzolan-Portland Cement Process c. Thermoplastic Microencapsulation d. Macroencapsulation e. Glassification f. Down Draft Sintering
		13. Ultraviolet Photolysis 14. Electron Beam 15. Gamma Irradiation	
		Thermal Treatment 1. Cryogenics	

MEDIA	RESPONSE ACTION	TECHNOLOGIES	PROCESSES
BUILDINGS (INCLUDES PROCESS PIPING AND TANKS)	DIRECT TREATMENT	Thermal Treatment	
		2. Thermal Desorption/Volatilization	a. Indirect Heating b. Radio-Frequency Heating c. Microwave Heating d. Hot Gas
		3. Surface Flashing/Flaming	
		4. Open Burning	
		5. Thermal Oxidation/Incineration	a. Rotary Hearth b. Multiple-Hearth c. Fluidized-Bed/Circulating-Bed d. Rotary Kiln e. Industrial Kiln f. Infrared Electric Furnace g. Pyrolysis/Electric Heater h. Submerged Quench Liquid Incineration i. Transportable Thermal Treatment Unit (TTTU) j. Low-Temperature Thermal Decomposition k. Wet Air Oxidation l. High-Temperature Fluid Wall (HTFW) m. Molten Salt/Sodium Fluxing n. Molten Glass o. Hot Plasma p. Supercritical Water Oxidation
		6. CO2 Laser	
	IN-SITU TREATMENT	Physical/Chemical Treatment	
		1. Vacuum Dusting 2. Hydraulic Scour 3. Mechanical Scour 4. Acid Etch 5. Drill/Spall 6. Scarification 7. Steam Cleaning 8. Sealant/Enclosure	
		Thermal Treatment	
		1. Cryogenics	
		2. Thermal Desorption/Volatilization	a. Indirect Heating b. Radio-Frequency Heating

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	PROCESSES
BUILDINGS (INCLUDES PROCESS PIPING AND TANKS)	IN-SITU TREATMENT	Thermal Treatment	
		2. Thermal Desorption/Volatilization	c. Microwave Heating d. Hot Gas
		3. Thermal Oxidation/Incineration	a. Infrared Radiant Heating b. Electrical Resistant Contact Heating c. Hot Plasma
		4. CO2 Laser	
	CONTAINMENT	1. Capping	a. Synthetic Membrane Liner b. Thermoplastic
	RECLAMATION	1. Site Rehabilitation	a. Resale for Scrap b. Reuse by the Army c. Building Restoration
AIR	REMOVAL	1. Elimination of Source	
	DIRECT TREATMENT	Physical/Chemical Treatment	
		1. Adsorption	a. Molecular Sieve
		2. Scrubbing 3. Precipitation 4. Filtration 5. Afterburners 6. Gas-Phase Carbon	
		Thermal Treatment	
		1. Thermal Oxidation/Incineration	a. Catalytic
	CONTAINMENT	1. Vapor Emission Control	a. Covers/Caps b. Gas Collection/Recovery
		2. Fugitive Dust Control	a. Chemical Spraying b. Water Spraying c. Wind Fences/Screens

TABLE 2.0-1. AVAILABLE TECHNOLOGIES AND PROCESSES

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	PROCESSES
BIOTA	REMOVAL	1. Selective Elimination 2. Relocation	
	DISPOSAL	1. Landfilling	a. Onsite Secure b. Offsite Secure c. Onsite Industrial d. Offsite Industrial e. Onsite Municipal f. Offsite Municipal
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS) 2. Stockpile/Waste Pile 3. Drums/Containers/Tanks	
	CONTAINMENT	1. Exclusion 2. Capture/Enclosure	
	RECLAMATION	1. Site Rehabilitation	a. Revegetation b. Habitat Restoration/Reintroduction

SOURCE: ESE, 1988.

TABLE 2.0-2. INNOVATIVE TECHNOLOGIES AND PROCESSES

09-Aug-88

RESPONSE ACTION	TECHNOLOGIES	PROCESSES
DIRECT AND/OR IN-SITU TREATMENT	Physical/Chemical Treatment	
	1. Electropolishing	
	2. Ultrasound	
	3. Washing/Flushing	
	4. Solidification and Stabilization	a. Thermoplastic Encapsulation
		b. Macroencapsulation
		c. Glassification
		d. Vitrification
		e. Polymerization
		f. Down Draft Sintering
	5. Dialysis	
	6. Electrodialysis	
	7. Adsorption	
		a. Permeable Treatment Beds
	8. Magnetic Separation	
	9. Vacuum Extraction	
	10. Chelation	
	11. Oxidation/Reduction	
		a. Ultraviolet-Ozone Treatment
	12. Chemical Dehalogenation	
		a. Alkali Metal
		b. Alkali Metal and Polyethylene Glycol (A/PEG)
	13. Ultraviolet Photolysis	
	14. Electron Beam	
	15. Gamma Irradiation	
	Biological Treatment	
	1. Aerobic	
		a. Bio-Uptake
		b. Biodegradation
		c. Enzymatic Degradation
	2. Anaerobic	
	Thermal Treatment	
	1. Cryogenics	
	2. Thermal Desorption/Volatilization	
		a. Indirect Heating
		b. Radio-Frequency Heating
		c. Microwave Heating
		d. Hot Gas
	3. Thermal Oxidation/Incineration	
		a. Infrared Electric Furnace
		b. Submerged Quench Liquid Incineration
		c. Wet Air Oxidation
		d. Molten Salt/Sodium Fluxing
		e. Molten Glass
		f. Electrical Resistant Contact Heating
		g. Hot Plasma
		h. Supercritical Water Oxidation
	4. CO2 Laser	
CONTAINMENT	1. Capping	
		a. Thermoplastic

SOURCE: ESE, 1988.

3.0 TECHNOLOGY SCREENING

The inventory of available technologies was screened in a two-step process in order to develop a list of applicable technologies for each Study Area at RMA. An applicable technology either independently or in combination with other technologies provides a reduction in mobility, toxicity, or volume of the contamination. The first step of the two-step screening process eliminated technologies not compatible with general RMA conditions. The second step of the screening process refined the inventory of screened, applicable technologies by considering the technology's compatibility with characteristics of each specific Study Area instead of characteristics of RMA as a whole. The second screening step was used to generate a list of applicable technologies for each Study Area.

Technology screening was performed using a set of tables as the basic organizational and recording tool. These tables are presented in Appendix B. Separate tables were constructed for the arsenal-wide screening and for each Study Area screening.

The first column of each table presents the type of media within the given Study Area. The second column lists the response actions which could be used to remediate contamination in a subject media. The third column presents technologies. To facilitate organization, in some cases the technologies are grouped according to their function or operating principles. These groups are then progressively broken down to available technologies. In cases where significant differences exist among them, process options considered within a technology are listed in Table 2.0-1. As an example in Appendix B, Table B-1, Soils/Sewers is the first medium. Soils/sewers may be remediated by several response actions, including direct treatment. Technologies under this response action are organized into groups, the first of which is Physical/Chemical Treatment. One technology in this group is dewatering, which includes centrifuges, gravity thickening, belt presses, plate and frame, drying beds, and vacuum filtration. All of these processes can be utilized for dewatering materials.

Each candidate technology was screened by applying a set of criteria designed to evaluate their applicability to the conditions, contaminants, and circumstances found at RMA. Screening included the following criteria:

- Site characteristics;
- Material/contaminant characteristics; and
- Technological limitations.

Specific criteria were developed for RMA within each of these areas and are explained in the following sections. These criteria were applied as objectively as possible, based upon professional judgement and acceptable engineering practices. A candidated technology that was not compatible with site or material/contaminant characteristics or was limited by technological considerations and was determine to most likely never be used at RMA, was rejected. For innovative technologies, technological limitations were not applied as a screening criterion.

3.1 SITE CHARACTERISTICS

The first criteria used in the technology screening process was site characteristics. Technologies were eliminated only if a limiting site condition occurs over the entire RMA or Study Area. Site characteristics applied in technology screening were:

- Hydrologic Conditions - Local ground water and/or surface water conditions such as depth to water, saturated thickness, and water use may be incompatible with certain technologies. Also, hydrologic conditions may not exist that warrant use of a specific technology. In some instances, application of a technology may increase rather than control migration due to hydrologic conditions
- Geologic Conditions - Because of subsurface conditions, some technologies may be ineffective or cause adverse impacts. Also, geologic conditions may not be technically appropriate or meet engineering design requirements for certain surface or subsurface structures;
- Site/Area Configuration - Because of the extremely large area of the RMA or specific Study Areas and sources, some technologies are inappropriate for site and area configurations. Conversely, other

technologies may require large areas which may not be available, for implementation. Site configuration, including shape, location and topography, may not be conducive to implementation of certain technologies; and

- Physical Condition - The physical condition refers to whether a particular contaminated medium exists at RMA or at each individual Study Area. In some Study Areas a particular condition may not exist which would therefore make a technology inappropriate.

3.2 MATERIAL/CONTAMINANT CHARACTERISTICS

Next, technologies were screened to evaluate their applicability to the types of contaminated material found at RMA or at each Study Area. Technologies that would not affect, would be hindered by, or would not mitigate contaminants were eliminated. Contaminant characteristics used in technology screening were:

- Physical state - Contaminated materials at RMA include liquids, solids, and vapors, or some combinations of these major categories. The effectiveness of a technology is directly related to the physical state of the material being addressed. In some cases, this may only marginally affect how a technology performs. In other instances, a technology may be completely ineffective or inappropriate for certain materials, and the technology may be eliminated because of the physical state of waste at RMA or at an individual Study Area;
- Quantity - The amount of contaminated material may be too large for certain technologies to address feasibly. Conversely, some technologies may require a minimum amount of material before application of the technology is warranted;
- Concentration - The concentration of contaminants in various environmental media at RMA may preclude some technologies from consideration. If the concentrations of contaminants in a given medium are too high or too low some technologies may be ineffective;
- Chemical Composition - Because of certain unique compounds or mixes of compounds that can be expected at RMA, some treatment options may not be applicable. The presence of some compounds may

render particular technologies unusable. Some chemical compounds may change to a more hazardous composition during treatment, thereby making a technology inappropriate. Technologies which disturb the current condition of acutely toxic materials may increase risk to workers and nearby residents; and

- Treatability - Treatability refers to compatibility of contaminated materials with treatment technologies and the ability of those technologies to significantly reduce mobility, toxicity, or volume of contaminated materials. Technologies which will not reduce these parameters were considered unsuitable for treatment of the contaminated materials in question.

3.3 TECHNOLOGICAL LIMITATIONS

The last criteria used in the technology screening was an evaluation of technological limitations which included:

- Implementation - Implementation describes the ease with which a technology could be brought online at RMA. Considerations include the technical, logistic, and political complexity of implementation, and the time required to construct and become operational. Technologies which present unreasonable implementation problems may be inappropriate; and
- Operation and Maintenance (O&M) - O&M involves the complexity, downtime and effort to maintain proper operation of a technology during its period of use. Technologies with low O&M requirements are considered preferable to those with high requirements if all other factors are equal. Unreasonable O&M requirements can render some technologies inappropriate.

As outlined in pertinent guidance documents, special consideration was given to innovative technologies. These were accepted if there was reasonable belief they may offer a better solution to certain problems than other available options.

4.0 ACCEPTED TECHNOLOGIES

The technologies which passed the screening steps discussed in the previous section are summarized in Tables 4.0-1 through 4.0-8. These tables list the technologies which appear to be useful in remediation of both RMA as a whole as well as remediation of each individual Study Area. The actual screening steps are documented in Appendix B, including rationale for elimination of specific technologies.

Because alternative remedial actions will initially be developed at the technology level, the summary tables only contain the technologies which pass the screening. During subsequent analysis and evaluation, processes which are representative of a type of technology may be used in order to allow for comparison of alternatives. The processes within each remedial technology category that may be used are listed in Table 2.0-1.

TABLE 4.0-1. ACCEPTED REMEDIAL TECHNOLOGIES -- ARSENAL-WIDE

04-Aug-88

RESPONSE ACTION	SOIL/SEWERS	WATER	BUILDINGS	AIR	BIOTA
REMOVAL	1. Demolition 2. Excavation 3. Dredging 4. Pumping 5. Materials Transport	1. Pumping 2. Materials Transport	1. Demolition 2. Excavation 3. Materials Transport	1. Elimination of Source	1. Selective Elimination 2. Relocation
DISPOSAL	1. Landfilling 2. Deep Well Injection 3. Above Ground Discharge	1. Deep Well Injection 2. Above Ground Discharge	1. Landfilling		1. Landfilling
STORAGE	1. Retrievable Monitored Containment Structure (RMCS) 2. Stockpile/Waste Pile 3. Surface Impoundment 4. Drums/Containers/Tanks	1. Retrievable Monitored Containment Structure (RMCS) 2. Surface Impoundment 3. Drums/Containers/Tanks	1. Retrievable Monitored Containment Structure (RMCS) 2. Stockpile/Waste Pile 3. Drums/Containers/Tanks		1. Retrievable Monitored Containment Structure (RMCS) 2. Stockpile/Waste Pile 3. Drums/Containers/Tanks
DIRECT TREATMENT	Physical/Chemical Treatment 1. Washing 2. Solidification and Stabilization 3. Volatilization (Natural) 4. Magnetic Separation 5. Dewatering 6. Neutralization 7. Hydrolysis 8. Ultraviolet Photolysis 9. Electron Beam 10. Gamma Irradiation Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment 1. Cryogenics 2. Evaporation 3. Thermal Desorption/ Volatilization 4. Surface Flashing/Flaming 5. Thermal Oxidation/ Incineration 6. CO2 Laser	Physical/Chemical Treatment 1. Solidification and Stabilization 2. Absorption 3. Magnetic Separation 4. Sedimentation 5. Flotation/Separation 6. Filtration/Separation 7. Dialysis 8. Electrodialysis 9. Solvent Extraction 10. Stripping 11. Steam Distillation 12. Adsorption 13. Neutralization 14. Precipitation/Flocculation 15. Chelation 16. Hydrolysis 17. Oxidation/Reduction 18. Chemical Dehalogenation 19. Ultraviolet Photolysis 20. Electron Beam 21. Gamma Irradiation Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment 1. Evaporation 2. Thermal Desorption/ Volatilization 3. Thermal Oxidation/ Incineration	Physical/Chemical Treatment 1. Washing 2. Vacuum Dusting 3. Hydraulic Scour 4. Mechanical Scour 5. Acid Etch 6. Drill/Spall 7. Scarification 8. Steam Cleaning 9. Sealant/Enclosure 10. Electropolishing 11. Ultrasound 12. Solidification and Stabilization 13. Ultraviolet Photolysis 14. Electron Beam 15. Gamma Irradiation Thermal Treatment 1. Cryogenics 2. Thermal Desorption 3. Surface Flashing/Flaming 4. Open Burning 5. Thermal Oxidation/ Incineration 6. CO2 Laser	Physical/Chemical Treatment 1. Adsorption 2. Scrubbing 3. Precipitation 4. Filtration 5. Afterburners 6. Gas-Phase Carbon Thermal Treatment 1. Thermal Oxidation/ Incineration	

TABLE 4.0-1. ACCEPTED REMEDIAL TECHNOLOGIES -- ARSENAL-WIDE

04-Aug-88

RESPONSE ACTION	SOIL/SEWERS	WATER	BUILDINGS	AIR	BIOTA
IN-SITU TREATMENT	Physical/Chemical Treatment 1. Solidification and Stabilization 2. Vacuum Extraction 3. Flushing 4. Venting 5. Chelation Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment 1. Evaporation 2. Thermal Desorption/ Volatilization	Physical/Chemical Treatment 1. Solidification and Stabilization 2. Adsorption 3. Neutralization 4. Precipitation/Flocculation 5. Chelation 6. Hydrolysis 7. Oxidation/Reduction Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment 1. Evaporation 2. Thermal Desorption/ Volatilization	Physical/Chemical Treatment 1. Vacuum Dusting 2. Hydraulic Scour 3. Mechanical Scour 4. Acid Etch 5. Drill/Spall 6. Scarification 7. Steam Cleaning 8. Sealant/Enclosure Thermal Treatment 1. Cryogenics 2. Thermal Desorption/ Volatilization 3. Thermal Oxidation/ Incineration 4. CO2 Laser		
CONTAINMENT	1. Subsurface Barriers 2. Subsurface Drains 3. Capping 4. Diversion	1. Subsurface Barriers 2. Subsurface Drains 3. Capping 4. Diversion	1. Capping	1. Vapor Emission Control 2. Fugitive Dust Control	1. Exclusion 2. Capture/Enclosure
RECLAMATION	1. Site Rehabilitation 2. Grouting/Relining	1. Site Rehabilitation	1. Site Rehabilitation		1. Site Rehabilitation

SOURCE: ESE, 1988.

RESPONSE ACTION	SOIL/SEWERS	WATER	BUILDINGS	AIR	BIOTA
REMOVAL	1. Demolition 2. Excavation 3. Dredging 4. Pumping 5. Materials Transport	1. Pumping 2. Materials Transport	1. Demolition 2. Excavation 3. Materials Transport	1. Elimination of Source	1. Selective Elimination 2. Relocation
DISPOSAL	1. Landfilling 2. Deep Well Injection 3. Above Ground Discharge	1. Deep Well Injection 2. Above Ground Discharge	1. Landfilling		1. Landfilling
STORAGE	1. Retrievable Monitored Containment Structure (RMCS) 2. Stockpile/Waste Pile 3. Surface Impoundment 4. Drums/Containers/Tanks	1. Retrievable Monitored Containment Structure (RMCS) 2. Surface Impoundment 3. Drums/Containers/Tanks	1. Retrievable Monitored Containment Structure (RMCS) 2. Stockpile/Waste Pile 3. Drums/Containers/Tanks		1. Retrievable Monitored Containment Structure (RMCS) 2. Stockpile/Waste Pile 3. Drums/Containers/Tanks
DIRECT TREATMENT	Physical/Chemical Treatment 1. Washing 2. Solidification and Stabilization 3. Volatilization (Natural) 4. Magnetic Separation 5. Dewatering 6. Neutralization 7. Hydrolysis 8. Ultraviolet Photolysis 9. Electron Beam 10. Gamma Irradiation Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment 1. Cryogenics 2. Evaporation 3. Thermal Desorption/ Volatilization 4. Surface Flashing/Flaming 5. Thermal Oxidation/ Incineration 6. CO2 Laser	Physical/Chemical Treatment 1. Solidification and Stabilization 2. Absorption 3. Magnetic Separation 4. Sedimentation 5. Flotation/Separation 6. Filtration/Separation 7. Dialysis 8. Electrodialysis 9. Solvent Extraction 10. Stripping 11. Steam Distillation 12. Adsorption 13. Neutralization 14. Precipitation/Flocculation 15. Chelation 16. Hydrolysis 17. Oxidation/Reduction 18. Chemical Dehalogenation 19. Ultraviolet Photolysis 20. Electron Beam 21. Gamma Irradiation Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment 1. Evaporation 2. Thermal Desorption/ Volatilization 3. Thermal Oxidation/ Incineration	Physical/Chemical Treatment 1. Washing 2. Vacuum Dusting 3. Hydraulic Scour 4. Mechanical Scour 5. Acid Etch 6. Drill/Spall 7. Scarification 8. Steam Cleaning 9. Sealant/Enclosure 10. Electropolishing 11. Ultrasound 12. Solidification and Stabilization 13. Ultraviolet Photolysis 14. Electron Beam 15. Gamma Irradiation Thermal Treatment 1. Cryogenics 2. Thermal Desorption 3. Surface Flashing/Flaming 4. Open Burning 5. Thermal Oxidation/ Incineration 6. CO2 Laser	Physical/Chemical Treatment 1. Adsorption 2. Scrubbing 3. Precipitation 4. Filtration 5. Afterburners 6. Gas-Phase Carbon Thermal Treatment 1. Thermal Oxidation/ Incineration	

TABLE 4.0-2. ACCEPTED REMEDIAL TECHNOLOGIES -- NORTH CENTRAL STUDY AREA

04-Aug-88

RESPONSE ACTION	SOIL/SEWERS	WATER	BUILDINGS	AIR	BIOTA
IN-SITU TREATMENT	Physical/Chemical Treatment 1. Solidification and Stabilization 2. Vacuum Extraction 3. Flushing 4. Venting 5. Chelation Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment 1. Evaporation 2. Thermal Desorption/ Volatilization	Physical/Chemical Treatment 1. Solidification and Stabilization 2. Adsorption 3. Neutralization 4. Precipitation/Flocculation 5. Chelation 6. Hydrolysis 7. Oxidation/Reduction Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment 1. Evaporation 2. Thermal Desorption/ Volatilization	Physical/Chemical Treatment 1. Vacuum Dusting 2. Hydraulic Scour 3. Mechanical Scour 4. Acid Etch 5. Drill/Spall 6. Scarification 7. Steam Cleaning 8. Sealant/Enclosure Thermal Treatment 1. Cryogenics 2. Thermal Desorption/ Volatilization 3. Thermal Oxidation/ Incineration 4. CO2 Laser		
CONTAINMENT	1. Subsurface Barriers 2. Subsurface Drains 3. Capping 4. Diversion	1. Subsurface Barriers 2. Subsurface Drains 3. Capping 4. Diversion	1. Capping	1. Vapor Emission Control 2. Fugitive Dust Control	1. Exclusion 2. Capture/Enclosure
RECLAMATION	1. Site Rehabilitation 2. Grouting/Relining	1. Site Rehabilitation	1. Site Rehabilitation		1. Site Rehabilitation

SOURCE: ESE, 1988.

TABLE 4.0-3. ACCEPTED REMEDIAL TECHNOLOGIES -- EAST STUDY AREA

04-Aug-88

RESPONSE ACTION	SOIL/SEWERS	WATER	BUILDINGS	AIR	BIOTA
REMOVAL	1. Excavation 3. Pumping 3. Materials Transport	1. Pumping 2. Materials Transport	1. Demolition 2. Excavation 3. Materials Transport	1. Elimination of Source	1. Selective Elimination 2. Relocation
DISPOSAL	1. Landfilling 2. Deep Well Injection 3. Above Ground Discharge	1. Deep Well Injection 2. Above Ground Discharge	1. Landfilling		1. Landfilling
STORAGE	1. Retrievable Monitored Containment Structure (RMCS) 2. Stockpile/Waste Pile 3. Surface Impoundment 4. Drums/Containers/Tanks	1. Retrievable Monitored Containment Structure (RMCS) 2. Surface Impoundment 3. Drums/Containers/Tanks	1. Retrievable Monitored Containment Structure (RMCS) 2. Stockpile/Waste Pile 3. Drums/Containers/Tanks		1. Retrievable Monitored Containment Structure (RMCS) 2. Stockpile/Waste Pile 3. Drums/Containers/Tanks
DIRECT TREATMENT	Physical/Chemical Treatment 1. Washing 2. Solidification and Stabilization 3. Volatilization (Natural) 4. Magnetic Separation 5. Dewatering 6. Hydrolysis 7. Ultraviolet Photolysis 8. Electron Beam 9. Gamma Irradiation Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment 1. Cryogenics 2. Evaporation 3. Thermal Desorption/ Volatilization 4. Surface Flashing/Flaming 5. Thermal Oxidation/ Incineration 6. CO2 Laser	Physical/Chemical Treatment 1. Solidification and Stabilization 2. Absorption 3. Magnetic Separation 4. Sedimentation 5. Flotation/Separation 6. Filtration/Separation 7. Dialysis 8. Electrodialysis 9. Solvent Extraction 10. Stripping 11. Steam Distillation 12. Adsorption 13. Neutralization 14. Precipitation/Flocculation 15. Chelation 16. Hydrolysis 17. Oxidation/Reduction 18. Chemical Dehalogenation 19. Ultraviolet Photolysis 20. Electron Beam 21. Gamma Irradiation Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment 1. Evaporation 2. Thermal Desorption/ Volatilization 3. Thermal Oxidation/ Incineration	Physical/Chemical Treatment 1. Washing 2. Vacuum Dusting 3. Hydraulic Scour 4. Mechanical Scour 5. Acid Etch 6. Drill/Spall 7. Scarification 8. Steam Cleaning 9. Sealant/Enclosure 10. Electropolishing 11. Ultrasound 12. Solidification and Stabilization 13. Ultraviolet Photolysis 14. Electron Beam 15. Gamma Irradiation Thermal Treatment 1. Cryogenics 2. Thermal Desorption 3. Surface Flashing/Flaming 4. Open Burning 5. Thermal Oxidation/ Incineration 6. CO2 Laser	Physical/Chemical Treatment 1. Adsorption 2. Scrubbing 3. Precipitation 4. Filtration 5. Afterburners 6. Gas-Phase Carbon Thermal Treatment 1. Thermal Oxidation/ Incineration	

TABLE 4.0-3. ACCEPTED REMEDIAL TECHNOLOGIES -- EAST STUDY AREA

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04-Aug-88

RESPONSE ACTION	SOIL/SEWERS	WATER	BUILDINGS	AIR	BIOTA
IN-SITU TREATMENT	Physical/Chemical Treatment 1. Solidification and Stabilization 2. Vacuum Extraction 3. Flushing 4. Venting 5. Chelation Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment 1. Evaporation 2. Thermal Desorption/ Volatilization	Physical/Chemical Treatment 1. Solidification and Stabilization 2. Adsorption 3. Neutralization 4. Precipitation/Flocculation 5. Chelation 6. Hydrolysis 7. Oxidation/Reduction Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment 1. Evaporation 2. Thermal Desorption/ Volatilization	Physical/Chemical Treatment 1. Vacuum Dusting 2. Hydraulic Scour 3. Mechanical Scour 4. Acid Etch 5. Drill/Spall 6. Scarification 7. Steam Cleaning 8. Sealant/Enclosure Thermal Treatment 1. Cryogenics 2. Thermal Desorption/ Volatilization 3. Thermal Oxidation/ Incineration 4. CO2 Laser		
CONTAINMENT	1. Subsurface Barriers 2. Subsurface Drains 3. Capping 4. Diversion	1. Subsurface Barriers 2. Subsurface Drains 3. Capping 4. Diversion	1. Capping	1. Vapor Emission Control 2. Fugitive Dust Control	1. Exclusion 2. Capture/Enclosure
RECLAMATION	1. Site Rehabilitation	1. Site Rehabilitation	1. Site Rehabilitation		1. Site Rehabilitation

SOURCE: ESE, 1988.

TABLE 4.0-4. ACCEPTED REMEDIAL TECHNOLOGIES -- SOUTH STUDY AREA

04-Aug-88

RESPONSE ACTION	SOIL/SEWERS	WATER	BUILDINGS	AIR	BIOTA
REMOVAL	1. Demolition 2. Excavation 3. Dredging 4. Pumping 5. Materials Transport	1. Pumping 2. Materials Transport	1. Demolition 2. Excavation 3. Materials Transport	1. Elimination of Source	1. Selective Elimination 2. Relocation
DISPOSAL	1. Landfilling 2. Deep Well Injection 3. Above Ground Discharge	1. Deep Well Injection 2. Above Ground Discharge	1. Landfilling		1. Landfilling
STORAGE	1. Retrievable Monitored Containment Structure (RMCS) 2. Stockpile/Waste Pile 3. Surface Impoundment 4. Drums/Containers/Tanks	1. Retrievable Monitored Containment Structure (RMCS) 2. Surface Impoundment 3. Drums/Containers/Tanks	1. Retrievable Monitored Containment Structure (RMCS) 2. Stockpile/Waste Pile 3. Drums/Containers/Tanks		1. Retrievable Monitored Containment Structure (RMCS) 2. Stockpile/Waste Pile 3. Drums/Containers/Tanks
DIRECT TREATMENT	Physical/Chemical Treatment 1. Washing 2. Solidification and Stabilization 3. Volatilization (Natural) 4. Magnetic Separation 5. Dewatering 6. Hydrolysis 7. Ultraviolet Photolysis 8. Electron Beam 9. Gamma Irradiation Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment 1. Cryogenics 2. Evaporation 3. Thermal Desorption/ Volatilization 4. Surface Flashing/Flaming 5. Thermal Oxidation/ Incineration 6. CO2 Laser	Physical/Chemical Treatment 1. Solidification and Stabilization 2. Magnetic Separation 3. Sedimentation 4. Filtration/Separation 5. Dialysis 6. Electrodialysis 7. Solvent Extraction 8. Stripping 9. Steam Distillation 10. Adsorption 11. Hydrolysis 12. Oxidation/Reduction 13. Chemical Dehalogenation 14. Ultraviolet Photolysis 15. Electron Beam 16. Gamma Irradiation Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment 1. Evaporation 2. Thermal Desorption/ Volatilization 3. Thermal Oxidation/ Incineration	Physical/Chemical Treatment 1. Washing 2. Vacuum Dusting 3. Hydraulic Scour 4. Mechanical Scour 5. Acid Etch 6. Drill/Spall 7. Scarification 8. Steam Cleaning 9. Sealant/Enclosure 10. Electropolishing 11. Ultrasound 12. Solidification and Stabilization 13. Ultraviolet Photolysis 14. Electron Beam 15. Gamma Irradiation Thermal Treatment 1. Cryogenics 2. Thermal Desorption 3. Surface Flashing/Flaming 4. Open Burning 5. Thermal Oxidation/ Incineration 6. CO2 Laser	Physical/Chemical Treatment 1. Adsorption 2. Scrubbing 3. Precipitation 4. Filtration 5. Afterburners 6. Gas-Phase Carbon Thermal Treatment 1. Thermal Oxidation/ Incineration	

TABLE 4.0-4. ACCEPTED REMEDIAL TECHNOLOGIES -- SOUTH STUDY AREA

04-Aug-88

RESPONSE ACTION	SOIL/SEWERS	WATER	BUILDINGS	AIR	BIOTA
IN-SITU TREATMENT	Physical/Chemical Treatment 1. Solidification and Stabilization 2. Vacuum Extraction 3. Flushing 4. Venting 5. Chelation Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment 1. Evaporation 2. Thermal Desorption/ Volatilization	Physical/Chemical Treatment 1. Solidification and Stabilization 2. Adsorption 3. Hydrolysis 4. Oxidation/Reduction Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment 1. Evaporation 2. Thermal Desorption/ Volatilization	Physical/Chemical Treatment 1. Vacuum Dusting 2. Hydraulic Scour 3. Mechanical Scour 4. Acid Etch 5. Drill/Spall 6. Scarification 7. Steam Cleaning 8. Sealant/Enclosure Thermal Treatment 1. Cryogenics 2. Thermal Desorption/ Volatilization 3. Thermal Oxidation/ Incineration 4. CO2 Laser		
CONTAINMENT	1. Subsurface Barriers 2. Subsurface Drains 3. Capping 4. Diversion	1. Subsurface Barriers 2. Subsurface Drains 3. Capping 4. Diversion	1. Capping	1. Vapor Emission Control 2. Fugitive Dust Control	1. Exclusion 2. Capture/Enclosure
RECLAMATION	1. Site Rehabilitation 2. Grouting/Relining	1. Site Rehabilitation	1. Site Rehabilitation		1. Site Rehabilitation

SOURCE: ESE, 1988.

TABLE 4.0-5. ACCEPTED REMEDIAL TECHNOLOGIES -- WEST STUDY AREA

04-Aug-88

RESPONSE ACTION	SOIL/SEWERS	WATER	BUILDINGS	AIR	BIOTA
REMOVAL	1. Demolition 2. Excavation 3. Pumping 4. Materials Transport	1. Pumping 2. Materials Transport	1. Demolition 2. Excavation 3. Materials Transport	1. Elimination of Source	1. Selective Elimination 2. Relocation
DISPOSAL	1. Landfilling 2. Deep Well Injection 3. Above Ground Discharge	1. Deep Well Injection 2. Above Ground Discharge	1. Landfilling		1. Landfilling
STORAGE	1. Retrievable Monitored Containment Structure (RMCS) 2. Stockpile/Waste Pile 3. Surface Impoundment 4. Drums/Containers/Tanks	1. Retrievable Monitored Containment Structure (RMCS) 2. Surface Impoundment 3. Drums/Containers/Tanks	1. Retrievable Monitored Containment Structure (RMCS) 2. Stockpile/Waste Pile 3. Drums/Containers/Tanks		1. Retrievable Monitored Containment Structure (RMCS) 2. Stockpile/Waste Pile 3. Drums/Containers/Tanks
DIRECT TREATMENT	Physical/Chemical Treatment 1. Washing 2. Solidification and Stabilization 3. Volatilization (Natural) 4. Magnetic Separation 5. Hydrolysis 6. Ultraviolet Photolysis 7. Electron Beam 8. Gamma Irradiation Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment 1. Cryogenics 2. Thermal Desorption/ Volatilization 3. Surface Flashing/ Flaming 4. CO2 Laser 5. Thermal Oxidation/ Incineration	Physical/Chemical Treatment 1. Solidification and Stabilization 2. Magnetic Separation 3. Flotation/Separation 4. Filtration/Separation 5. Dialysis 6. Electrodialysis 7. Solvent Extraction 8. Stripping 9. Steam Distillation 10. Adsorption 11. Hydrolysis 12. Oxidation/Reduction 13. Chemical Dehalogenation 14. Ultraviolet Photolysis 15. Electron Beam 16. Gamma Irradiation Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment . 1. Evaporation 2. Thermal Desorption/ Volatilization 3. Thermal Oxidation/ Incineration	Physical/Chemical Treatment 1. Washing 2. Vacuum Dusting 3. Hydraulic Scour 4. Mechanical Scour 5. Acid Etch 6. Drill/Spall 7. Scarification 8. Steam Cleaning 9. Sealant/Enclosure 10. Electropolishing 11. Ultrasound 12. Solidification and Stabilization 13. Ultraviolet Photolysis 14. Electron Beam 15. Gamma Irradiation Thermal Treatment 1. Cryogenics 2. Thermal Desorption 3. Surface Flashing/Flaming 4. Open Burning 5. Thermal Oxidation/ Incineration 6. CO2 Laser	Physical/Chemical Treatment 1. Adsorption 2. Scrubbing 3. Precipitation 4. Filtration 5. Afterburners 6. Gas-Phase Carbon Thermal Treatment 1. Thermal Oxidation/ Incineration	

TABLE 4.0-5. ACCEPTED REMEDIAL TECHNOLOGIES -- WEST STUDY AREA

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RESPONSE ACTION	SOIL/SEWERS	WATER	BUILDINGS	AIR	BIOTA
IN-SITU TREATMENT	**Physical/Chemical Treatment** 1. Solidification and Stabilization 2. Vacuum Extraction 3. Flushing 4. Venting 5. Chelation **Biological Treatment** 1. Aerobic 2. Anaerobic **Thermal Treatment** 1. Thermal Desorption/ Volatilization	**Physical/Chemical Treatment** 1. Solidification and Stabilization 2. Adsorption 3. Hydrolysis 4. Oxidation/Reduction **Biological Treatment** 1. Aerobic 2. Anaerobic **Thermal Treatment** 1. Evaporation 2. Thermal Desorption/ Volatilization	**Physical/Chemical Treatment** 1. Vacuum Dusting 2. Hydraulic Scour 3. Mechanical Scour 4. Acid Etch 5. Drill/Spall 6. Scarification 7. Steam Cleaning 8. Sealant/Enclosure **Thermal Treatment** 1. Cryogenics 2. Thermal Desorption/ Volatilization 3. Thermal Oxidation/ Incineration 4. CO2 Laser		
CONTAINMENT	1. Subsurface Barriers 2. Subsurface Drains 3. Capping 4. Diversion	1. Subsurface Barriers 2. Subsurface Drains 3. Capping 4. Diversion	1. Capping	1. Vapor Emission Control 2. Fugitive Dust Control	1. Exclusion 2. Capture/Enclosure
RECLAMATION	1. Site Rehabilitation 2. Grouting/Relining	1. Site Rehabilitation	1. Site Rehabilitation		1. Site Rehabilitation

SOURCE: ESE, 1988.

TABLE 4.0-6. ACCEPTED REMEDIAL TECHNOLOGIES -- CENTRAL STUDY AREA

04-Aug-88

RESPONSE ACTION	SOIL/SEWERS	WATER	BUILDINGS	AIR	BIOTA
REMOVAL	1. Demolition 2. Excavation 3. Pumping 4. Materials Transport	1. Pumping 2. Materials Transport	1. Demolition 2. Excavation 3. Materials Transport	1. Elimination of Source	1. Selective Elimination 2. Relocation
DISPOSAL	1. Landfilling 2. Deep Well Injection 3. Above Ground Discharge	1. Deep Well Injection 2. Above Ground Discharge	1. Landfilling		1. Landfilling
STORAGE	1. Retrievable Monitored Containment Structure (RMCS) 2. Stockpile/Waste Pile 3. Drums/Containers/Tanks	1. Retrievable Monitored Containment Structure (RMCS) 2. Surface Impoundment 3. Drums/Containers/Tanks	1. Retrievable Monitored Containment Structure (RMCS) 2. Stockpile/Waste Pile 3. Drums/Containers/Tanks		1. Retrievable Monitored Containment Structure (RMCS) 2. Stockpile/Waste Pile 3. Drums/Containers/Tanks
DIRECT TREATMENT	Physical/Chemical Treatment 1. Washing 2. Solidification and Stabilization 3. Volatilization (Natural) 4. Magnetic Separation 5. Ultraviolet Photolysis 6. Electron Beam 7. Gamma Irradiation Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment 1. Cryogenics 2. Evaporation 3. Thermal Desorption/ Volatilization 4. Surface Flashing/Flaming 5. Thermal Oxidation/ Incineration 6. CO2 Laser	Physical/Chemical Treatment 1. Solidification and Stabilization 2. Absorption 3. Magnetic Separation 4. Flotation/Separation 5. Filtration/Separation 6. Dialysis 7. Electrodialysis 8. Solvent Extraction 9. Stripping 10. Steam Distillation 11. Adsorption 12. Neutralization 13. Precipitation/Flocculation 14. Chelation 15. Hydrolysis 16. Oxidation/Reduction 17. Chemical Dehalogenation 18. Ultraviolet Photolysis 19. Electron Beam 20. Gamma Irradiation Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment 1. Evaporation 2. Thermal Desorption/ Volatilization 3. Thermal Oxidation/ Incineration	Physical/Chemical Treatment 1. Washing 2. Vacuum Dusting 3. Hydraulic Scour 4. Mechanical Scour 5. Acid Etch 6. Drill/Spall 7. Scarification 8. Steam Cleaning 9. Sealant/Enclosure 10. Electropolishing 11. Ultrasound 12. Solidification and Stabilization 13. Ultraviolet Photolysis 14. Electron Beam 15. Gamma Irradiation Thermal Treatment 1. Cryogenics 2. Thermal Desorption 3. Surface Flashing/Flaming 4. Open Burning 5. Thermal Oxidation/ Incineration 6. CO2 Laser	Physical/Chemical Treatment 1. Adsorption 2. Scrubbing 3. Precipitation 4. Filtration 5. Afterburners 6. Gas-Phase Carbon Thermal Treatment 1. Thermal Oxidation/ Incineration	

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RESPONSE ACTION	SOIL/SEWERS	WATER	BUILDINGS	AIR	BIOTA
IN-SITU TREATMENT	Physical/Chemical Treatment 1. Solidification and Stabilization 2. Vacuum Extraction 3. Flushing 4. Venting 5. Chelation Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment 1. Evaporation 2. Thermal Desorption/ Volatilization	Physical/Chemical Treatment 1. Solidification and Stabilization 2. Adsorption 3. Precipitation/Flocculation 4. Chelation 5. Hydrolysis 6. Oxidation/Reduction Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment 1. Thermal Desorption/ Volatilization	Physical/Chemical Treatment 1. Vacuum Dusting 2. Hydraulic Scour 3. Mechanical Scour 4. Acid Etch 5. Drill/Spall 6. Scarification 7. Steam Cleaning 8. Sealant/Enclosure Thermal Treatment 1. Cryogenics 2. Thermal Desorption/ Volatilization 3. Thermal Oxidation/ Incineration 4. CO2 Laser		
CONTAINMENT	1. Subsurface Barriers 2. Subsurface Drains 3. Capping 4. Diversion	1. Subsurface Barriers 2. Subsurface Drains 3. Capping 4. Diversion	1. Capping	1. Vapor Emission Control 2. Fugitive Dust Control	1. Exclusion 2. Capture/Enclosure
RECLAMATION	1. Site Rehabilitation 2. Grouting/Relining	1. Site Rehabilitation	1. Site Rehabilitation		1. Site Rehabilitation

SOURCE: ESE, 1988.

TABLE 4.0-7. ACCEPTED REMEDIAL TECHNOLOGIES -- NORTH PLANTS STUDY AREA

04-Aug-88

RESPONSE ACTION	SOIL/SEWERS	WATER	BUILDINGS	AIR	BIOTA
REMOVAL	1. Demolition 2. Excavation 3. Dredging 4. Pumping 5. Materials Transport	1. Pumping 2. Materials Transport	1. Demolition 2. Excavation 3. Materials Transport	1. Elimination of Source	1. Selective Elimination 2. Relocation
DISPOSAL	1. Landfilling 2. Deep Well Injection 3. Above Ground Discharge	1. Deep Well Injection 2. Above Ground Discharge	1. Landfilling		1. Landfilling
STORAGE	1. Retrievable Monitored Containment Structure (RMCS) 2. Stockpile/Waste Pile 3. Surface Impoundment 4. Drums/Containers/Tanks	1. Retrievable Monitored Containment Structure (RMCS) 2. Surface Impoundment 3. Drums/Containers/Tanks	1. Retrievable Monitored Containment Structure (RMCS) 2. Stockpile/Waste Pile 3. Drums/Containers/Tanks		1. Retrievable Monitored Containment Structure (RMCS) 2. Stockpile/Waste Pile 3. Drums/Containers/Tanks
DIRECT TREATMENT	Physical/Chemical Treatment 1. Washing 2. Solidification and Stabilization 3. Volatilization (Natural) 4. Magnetic Separation 5. Dewatering 6. Neutralization 7. Hydrolysis 8. Ultraviolet Photolysis 9. Electron Beam 10. Gamma Irradiation Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment 1. Cryogenics 2. Evaporation 3. Thermal Desorption/ Volatilization 4. Surface Flashing/Flaming 5. Thermal Oxidation/ Incineration 6. CO2 Laser	Physical/Chemical Treatment 1. Solidification and Stabilization 2. Absorption 3. Magnetic Separation 4. Sedimentation 5. Flotation/Separation 6. Filtration/Separation 7. Dialysis 8. Electrodialysis 9. Solvent Extraction 10. Stripping 11. Steam Distillation 12. Adsorption 13. Neutralization 14. Precipitation/Flocculation 15. Chelation 16. Hydrolysis 17. Oxidation/Reduction 18. Chemical Dehalogenation 19. Ultraviolet Photolysis 20. Electron Beam 21. Gamma Irradiation Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment 1. Evaporation 2. Thermal Desorption/ Volatilization 3. Thermal Oxidation/ Incineration	Physical/Chemical Treatment 1. Washing 2. Vacuum Dusting 3. Hydraulic Scour 4. Mechanical Scour 5. Acid Etch 6. Drill/Spall 7. Scarification 8. Steam Cleaning 9. Sealant/Enclosure 10. Electropolishing 11. Ultrasound 12. Solidification and Stabilization 13. Ultraviolet Photolysis 14. Electron Beam 15. Gamma Irradiation Thermal Treatment 1. Cryogenics 2. Thermal Desorption 3. Surface Flashing/Flaming 4. Open Burning 5. Thermal Oxidation/ Incineration 6. CO2 Laser	Physical/Chemical Treatment 1. Adsorption 2. Scrubbing 3. Precipitation 4. Filtration 5. Afterburners 6. Gas-Phase Carbon Thermal Treatment 1. Thermal Oxidation/ Incineration	

TABLE 4.0-7. ACCEPTED REMEDIAL TECHNOLOGIES -- NORTH PLANTS STUDY AREA

04-Aug-88

RESPONSE ACTION	SOIL/SEWERS	WATER	BUILDINGS	AIR	BIOTA
IN-SITU TREATMENT	Physical/Chemical Treatment 1. Solidification and Stabilization 2. Vacuum Extraction 3. Flushing 4. Venting 5. Chelation Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment 1. Evaporation 2. Thermal Desorption/ Volatilization	Physical/Chemical Treatment 1. Solidification and Stabilization 2. Adsorption 3. Neutralization 4. Precipitation/Flocculation 5. Chelation 6. Hydrolysis 7. Oxidation/Reduction Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment 1. Evaporation 2. Thermal Desorption/ Volatilization	Physical/Chemical Treatment 1. Vacuum Dusting 2. Hydraulic Scour 3. Mechanical Scour 4. Acid Etch 5. Drill/Spall 6. Scarification 7. Steam Cleaning 8. Sealant/Enclosure Thermal Treatment 1. Cryogenics 2. Thermal Desorption/ Volatilization 3. Thermal Oxidation/ Incineration 4. CO2 Laser		
CONTAINMENT	1. Subsurface Barriers 2. Subsurface Drains 3. Capping 4. Diversion	1. Subsurface Barriers 2. Subsurface Drains 3. Capping 4. Diversion	1. Capping	1. Vapor Emission Control 2. Fugitive Dust Control	1. Exclusion 2. Capture/Enclosure
RECLAMATION	1. Site Rehabilitation 2. Grouting/Relining	1. Site Rehabilitation	1. Site Rehabilitation		1. Site Rehabilitation

SOURCE: ESE, 1988.

TABLE 4.0-8. ACCEPTED REMEDIAL TECHNOLOGIES -- SOUTH PLANTS STUDY AREA

04-Aug-88

RESPONSE ACTION	SOIL/SEWERS	WATER	BUILDINGS	AIR	BIOTA
REMOVAL	1. Demolition 2. Excavation 3. Dredging 4. Pumping 5. Materials Transport	1. Pumping 2. Materials Transport	1. Demolition 2. Excavation 3. Materials Transport	1. Elimination of Source	1. Selective Elimination 2. Relocation
DISPOSAL	1. Landfilling 2. Deep Well Injection 3. Above Ground Discharge	1. Deep Well Injection 2. Above Ground Discharge	1. Landfilling		1. Landfilling
STORAGE	1. Retrievable Monitored Containment Structure (RMCS) 2. Stockpile/Waste Pile 3. Surface Impoundment 4. Drums/Containers/Tanks	1. Retrievable Monitored Containment Structure (RMCS) 2. Surface Impoundment 3. Drums/Containers/Tanks	1. Retrievable Monitored Containment Structure (RMCS) 2. Stockpile/Waste Pile 3. Drums/Containers/Tanks		1. Retrievable Monitored Containment Structure (RMCS) 2. Stockpile/Waste Pile 3. Drums/Containers/Tanks
DIRECT TREATMENT	Physical/Chemical Treatment 1. Washing 2. Solidification and Stabilization 3. Volatilization (Natural) 4. Magnetic Separation 5. Dewatering 6. Neutralization 7. Hydrolysis 8. Ultraviolet Photolysis 9. Electron Beam 10. Gamma Irradiation Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment 1. Cryogenics 2. Evaporation 3. Thermal Desorption/ Volatilization 4. Surface Flashing/Flaming 5. Thermal Oxidation/ Incineration 6. CO2 Laser	Physical/Chemical Treatment 1. Solidification and Stabilization 2. Absorption 3. Magnetic Separation 4. Sedimentation 5. Flotation/Separation 6. Filtration/Separation 7. Dialysis 8. Electrodialysis 9. Solvent Extraction 10. Stripping 11. Steam Distillation 12. Adsorption 13. Neutralization 14. Precipitation/Flocculation 15. Chelation 16. Hydrolysis 17. Oxidation/Reduction 18. Chemical Dehalogenation 19. Ultraviolet Photolysis 20. Electron Beam 21. Gamma Irradiation Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment 1. Evaporation 2. Thermal Desorption/ Volatilization 3. Thermal Oxidation/ Incineration	Physical/Chemical Treatment 1. Washing 2. Vacuum Dusting 3. Hydraulic Scour 4. Mechanical Scour 5. Acid Etch 6. Drill/Spall 7. Scarification 8. Steam Cleaning 9. Sealant/Enclosure 10. Electropolishing 11. Ultrasound 12. Solidification and Stabilization 13. Ultraviolet Photolysis 14. Electron Beam 15. Gamma Irradiation Thermal Treatment 1. Cryogenics 2. Thermal Desorption 3. Surface Flashing/Flaming 4. Open Burning 5. Thermal Oxidation/ Incineration 6. CO2 Laser	Physical/Chemical Treatment 1. Adsorption 2. Scrubbing 3. Precipitation 4. Filtration 5. Afterburners 6. Gas-Phase Carbon Thermal Treatment 1. Thermal Oxidation/ Incineration	

TABLE 4.0-8. ACCEPTED REMEDIAL TECHNOLOGIES -- SOUTH PLANTS STUDY AREA

04-Aug-88

RESPONSE ACTION	SOIL/SEWERS	WATER	BUILDINGS	AIR	BIOTA
IN-SITU TREATMENT	Physical/Chemical Treatment 1. Solidification and Stabilization 2. Vacuum Extraction 3. Flushing 4. Venting 5. Chelation Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment 1. Evaporation 2. Thermal Desorption/ Volatilization	Physical/Chemical Treatment 1. Solidification and Stabilization 2. Adsorption 3. Neutralization 4. Precipitation/Flocculation 5. Chelation 6. Hydrolysis 7. Oxidation/Reduction Biological Treatment 1. Aerobic 2. Anaerobic Thermal Treatment 1. Evaporation 2. Thermal Desorption/ Volatilization	Physical/Chemical Treatment 1. Vacuum Dusting 2. Hydraulic Scour 3. Mechanical Scour 4. Acid Etch 5. Drill/Spall 6. Scarification 7. Steam Cleaning 8. Sealant/Enclosure Thermal Treatment 1. Cryogenics 2. Thermal Desorption/ Volatilization 3. Thermal Oxidation/ Incineration 4. CO2 Laser		
CONTAINMENT	1. Subsurface Barriers 2. Subsurface Drains 3. Capping 4. Diversion	1. Subsurface Barriers 2. Subsurface Drains 3. Capping 4. Diversion	1. Capping	1. Vapor Emission Control 2. Fugitive Dust Control	1. Exclusion 2. Capture/Enclosure
RECLAMATION	1. Site Rehabilitation 2. Grouting/Relining	1. Site Rehabilitation	1. Site Rehabilitation		1. Site Rehabilitation

SOURCE: ESE, 1988.

5.0 DATA NEEDS

As a result of the technology inventory and screening process, potential information gaps were identified and are summarized here. These data gaps represent a preliminary list of technologies for which either literature searches may be necessary, or for which treatability studies may be needed in order to complete the alternatives development and analysis.

Table 5.0-1 summarizes the technologies and processes that do not have significant data bases of either general information or, if necessary, RMA-specific information. This is a preliminary list that may be revised as the alternatives are more fully developed and analyzed.

The collection of information will start with a search of existing literature to determine if sources at RMA or outside of RMA have sufficient technological data to address the needs of the FS. If there is not an adequate data base or if RMA-specific data is not available, an evaluation will be made of the need for treatability studies.

TABLE 5.0-1. TECHNOLOGIES/PROCESSES THAT MAY REQUIRE ADDITIONAL CHARACTERIZATION

09-Aug-88

RESPONSE ACTION	TECHNOLOGIES	PROCESSES
DIRECT AND/OR IN-SITU TREATMENT	Physical/Chemical Treatment	
	1. Electropolishing	
	2. Ultrasound	
	3. Washing/Flushing	
	4. Solidification and Stabilization	a. Thermoplastic Encapsulation
		b. Macroencapsulation
		c. Glassification
		d. Vitrification
		e. Polymerization
		f. Down Draft Sintering
	5. Dialysis	
	6. Electrodialysis	
	7. Adsorption	
		a. Permeable Treatment Beds
		b. Ion Exchange and Sorptive Resins
	8. Magnetic Separation	
	9. Vacuum Extraction	
	10. Chelation	
	11. Oxidation/Reduction	
		a. Ultraviolet-Ozone Treatment
	12. Chemical Dehalogenation	
		a. Alkali Metal
		b. Alkali Metal and Polyethylene Glycol (A/PEG)
	13. Ultraviolet Photolysis	
	14. Electron Beam	
	15. Gamma Irradiation	
	Biological Treatment	
	1. Aerobic	
		a. Bio-Uptake
		b. Biodegradation
		c. Enzymatic Degradation
		d. Powdered Activated Carbon Treatment (PACT)
	2. Anaerobic	
	Thermal Treatment	
	1. Cryogenics	
	2. Thermal Desorption/Volatilization	
		a. Indirect Heating
		b. Radio-Frequency Heating
		c. Microwave Heating
		d. Hot Gas
	3. Thermal Oxidation/Incineration	
		a. Infrared Electric Furnace
		b. Submerged Quench Liquid Incineration
		c. Wet Air Oxidation
		d. High-Temperature Fluid Wall (HTFW)
		e. Molten Salt/Sodium Fluxing
		f. Molten Glass
		g. Electrical Resistant Contact Heating
		h. Hot Plasma
		i. Supercritical Water Oxidation
	4. CO2 Laser	
CONTAINMENT	1. Capping	
		a. Thermoplastic

SOURCE: ESE, 1988.

APPENDIX A

TECHNOLOGY AND PROCESS DESCRIPTIONS

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1.0 REMOVAL

Removal includes extraction and transfer of contaminated material from a site. In this section, five removal technologies are discussed, which can usually be accomplished with conventional heavy construction equipment.

1.1 DEMOLITION

Demolition refers to the destruction of a building, structure, or piece of equipment. Specific demolition techniques include burndown, controlled blasting, wrecking with balls or backhoe-mounted rams, rock splitting, sawing, drilling or crushing. Drawbacks to this technology are large quantities of contaminated debris must be properly disposed and airborne contamination may occur through fugitive emissions.

1.2 EXCAVATION

Excavation is the process of removing soil, rock, or other materials. Excavation followed by disposal or treatment is performed extensively in hazardous waste site remediation. Excavation on a large scale is achieved mechanically by conventional heavy construction equipment.

Excavation can remove contamination from a site and minimize long-term monitoring requirements. Once excavation has begun, the time to achieve beneficial results can be short relative to such alternatives as in-situ treatment. Excavation can be used in combination with most other remedial technologies.

Several disadvantages associated with excavation are worker safety, short-term impacts, and implementation. Where highly hazardous or toxic materials are present, excavation may pose a substantial risk to worker safety. Short-term impacts such as fugitive dust emissions, toxic gases, and contaminated runoff are frequently a major concern.

1.3 DREDGING

Contamination of sediments in streams, ponds, lakes, and other water bodies may occur via several different pathways. Contaminated soil may be eroded from the surface of hazardous waste disposal sites by runoff and be

deposited in nearby watercourses or sediment basins constructed downslope of the site. Existing sediments along stream bottoms may absorb contaminants that have been washed into the watercourse, entered from contaminated ground water seepage, or resulted from spills of hazardous chemicals denser than water.

Remedial techniques for contaminated sediments generally involve physical removal and subsequent treatment and disposal of the recovered sediment. During the removal of contaminated sediments, specific techniques are used to minimize the threat of further environmental harm through resuspension of contaminants.

1.3.1 MECHANICAL

Mechanical dredging involves the use of excavation equipment such as backhoes, draglines, clamshells, and bucket-ladder dredges. Draglines and clamshells used for dredging are usually vessel mounted, but can also be track mounted and land based.

The main advantage of mechanical dredging is removal of sediments at nearly in-situ densities, therefore maximizing solids content and minimizing the scale of facilities required for dredged material transport, treatment, and disposal. However, because mechanical dredging removes bottom sediment through direct application of mechanical force to dislodge the material, sediment resuspension is often high. Also, mechanical dredging is relatively ineffective in the removal of free or unabsorbed liquid contaminants, and has a low production rate. It is generally used in shallow streams and rivers with relatively low flow velocities. It is also used for removing contaminated sediments deposited on dry river banks or in floodplains.

1.3.2 HYDRAULIC

Hydraulic dredges remove and transport sediment and sludges in slurries containing 10 to 20 percent solids. Slurries can be pumped through pontoon-supported pipelines to a treatment/storage area. Hydraulic dredges usually are barge mounted and carry diesel-powered centrifugal pumps. The major disadvantage of hydraulic dredges is a large flow rate associated with

pumping at low solids concentrations, resulting in the need for large areas of land for settling/dewatering.

1.3.3 PNEUMATIC

Pneumatic dredges operate on compressed air and hydrostatic pressure to draw sediments to the collection head and through the transport piping. Pneumatic dredges are similar to hydraulic dredges but may yield denser slurries with lower levels of turbidity and resuspension of solids, although at a reduced rate of production.

1.4 PUMPING

Pumping is required to remove liquids and sludges from ponds, lagoons, tanks, and surface impoundments and can be used to control ground-water movement. Liquid wastes pumped from containment are generally transferred to a treatment system or tank truck for transport to a hazardous waste management facility (HWMF). Several types of pumps can be utilized including centrifugal; reciprocating (diaphragm and piston pumps); displacement (gear, impeller); immersion; and submersible. Industrial vacuum loaders can be used in large-scale cleanup operations to remove sludge or pools of liquid waste.

Ground-water pumping techniques involve the active manipulation and management of ground water to contain or remove a plume, or to adjust ground-water levels to prevent formation of a plume. Types of wells used in management of contaminated ground water include well points, suction wells, ejector wells, and deep wells. The selection of the appropriate well type depends on the depth of contamination and the hydrologic and geologic characteristics of the aquifer.

1.4.1 WELL POINTS

Well point systems consist of a group of closely spaced wells connected to a header pipe and pumped by a suction pump. Well points are best suited for ground-water extraction in stratified soils where total lift or drawdown will not exceed 22 feet (ft). The advantages to using well points are that the system design is flexible and the well points are relatively simple to operate and maintain.

1.4.2 EXTRACTION/INJECTION WELLS

Extraction wells can be used at contaminated sites to remove contaminated ground water for treatment, lower the water table in a particular area, and/or contain a plume of contaminated ground water. When large quantities of ground water are extracted or when the ground water is a drinking water source, recharge of the treated ground water by injection wells may be necessary.

Extraction well systems utilize one or more pumps to draw ground water to the surface, with a cone of depression resulting from the drawdown of ground water at each well. With proper placement and operation, the resulting drawdown can act as a hydraulic barrier to impede contaminated ground-water migration. Therefore, extraction wells can serve as both a ground-water containment and collection technology.

An extraction well system may be a more easily implemented method of ground water containment than impermeable barriers. Extraction/injection wells also have a moderate to high operational flexibility, which allows the system to meet increased or decreased pumping demands.

A disadvantage of extraction wells is that system failures could lead to contaminated ground water migration. Operation and maintenance requirements generally are higher for extraction wells than for impermeable barriers.

1.5 MATERIALS TRANSPORT

The transportation of hazardous wastes is regulated by the U.S. Department of Transportation (DOT), the U.S. Environmental Protection Agency (EPA), state governments, and, in some instances, local ordinances and codes. In addition, more stringent Federal regulations govern the transportation and disposal of highly toxic and hazardous materials such as polychlorinated biphenyls (PCBs) and radioactive wastes.

Vehicles for offsite transport of hazardous wastes must be DOT approved and must display the proper DOT placard. Liquid wastes must be hauled in tanker trucks that meet requirements and specifications for the waste types.

Contaminated soils are generally hauled in box trailers or sometimes rail cars, while drums are hauled in box trailers or on flatbed trucks. Materials transport within a site can utilize a variety of special vehicles and also conveyor systems such as those commonly used in mining operations.

2.0 DISPOSAL

Disposal refers to the group of technologies that involve the final disposition of waste material in facilities with varying degrees of security. That is, hazardous materials may be disposed of in secure landfills where as nonhazardous wastes may be disposed of in municipal landfills. Wastes may also be disposed of in industrial landfills or used as backfill material depending on the material's characteristics. Other disposal techniques may include deep well injection for liquids or above ground discharge of uncontaminated soils, waters or other clean materials. The materials to be disposed of may or may not be treated.

2.1 LANDFILLING

Landfill disposal has to date been the most commonly practiced method of disposal of municipal, industrial, and hazardous wastes. The primary advantage of landfilling is simplicity compared to other technologies capable of handling a high volume of contaminated solids. Implementation time is also much shorter than for most treatment options.

2.1.1 SECURE LANDFILL

Secure landfills for hazardous wastes are typically constructed with impermeable bottom and side liners, leachate collection and treatment systems, and impermeable caps incorporating surface water controls. RCRA requirements under 40 CFR Part 264 (Subpart N) and associated guidance describe the proper design, construction, operation, and maintenance of hazardous waste landfills. Regulatory changes will impact the suitability and relative desirability of landfilling for redisposal of CERCLA wastes in the future.

According to RCRA requirements, landfills must have an impermeable double-liner system constructed of materials of sufficient strength and thickness to prevent failure due to pressure gradients, physical contact with the waste or leachates, climatic conditions, and stress of installation and daily operation. In addition, the landfill must have a leachate collection and removal system immediately above the top liner, which must also be able to withstand routine stress and function without clogging through the

scheduled closure of the landfill. The cover system for the landfill must provide for long-term minimization of migration of liquids through the closed landfill, promote drainage and minimize erosion or abrasion of the cover, and meet other closure and post-closure requirements for landfills as specified under RCRA (40 CFR 264.310).

Liquids, certain highly toxic and/or highly mobile wastes, and reactive wastes are restricted from landfills by RCRA regulations. Additional restrictions on landfilling will likely be encountered in the future. In addition, post-closure maintenance of an onsite landfill can be a significant commitment over the 30-year post-closure period. The landfill site must be restricted from public access to prevent damage to the cover system.

2.1.2 INDUSTRIAL LANDFILL

Industrial Landfills are designed and operated like secure landfills. However, Industrial Landfills accept only non-RCRA listed chemical waste: liquids, reactive waste, and other highly toxic wastes are also restricted from Industrial Landfills.

2.1.3 MUNICIPAL LANDFILL

Municipal landfills are most often unlined and therefore suitable to receive only nonhazardous wastes. These landfills generally receive all wastes associated with municipalities specifically excluding hazardous, agricultural and mining wastes. Municipal landfills can be used for disposal of CERCLA wastes that are treated and/or stabilized appropriately.

2.1.4 BACKFILL

Backfilling is one method of disposing of soil that has been excavated and treated. Backfilling reduces expenses to replace soil in excavations and dispose of soil in landfills. However, contaminated soil can only be backfilled after the soil has been effectively treated.

2.2 DEEP WELL INJECTION

Deep well injection involves pumping liquids into the pores of deep subsurface geological formations substantially below usable freshwater

aquifers. The liquid is typically injected into a geologically confined formation containing saline or otherwise unusable ground water. Experience with deep well injection of hazardous waste has been obtained primarily from commercial and industrial operations injecting acidic wastes and waste brines of uniform characteristics, respectively. Commercial injection generally occurs in the Texas-Louisiana-Oklahoma region.

2.3 ABOVE GROUND DISCHARGE

Above ground discharge includes discharge to surface streams and publicly owned treatment works (POTWs). Surface discharges are often used for treated wastewaters from decontamination, soil washing, groundwater extraction, and other such remedial actions. Special considerations when discharging to surface streams are water quality standards, public opinion, environmental impacts, and federal and state permitting requirements. Discharge to POTW's is limited by available treatment capacity and permit and pretreatment requirements.

In some instances, discharge to specially constructed infiltration basins can be used. This offers the opportunity to utilize the natural treatment capabilities of the soil, provide some driving force to enhance contaminant leaching, and recharge groundwater in selected areas. This can be especially useful in certain types of groundwater extraction and treatment systems.

Above ground discharge may also include soil or sediments. Soil discharges will have quantity limitations, and will also have to consider appropriate regulations, public opinion, environmental impacts and Federal and State permitting requirements.

3.0 STORAGE

Storage of hazardous waste is defined as the holding of hazardous materials for a temporary period after which the material is treated, disposed, or stored elsewhere. Hazardous waste can be stored and contained in tanks, surface impoundments or drums, or other acceptable containers. A container is any portable device in which a material is stored, transported, treated, or disposed.

3.1 RETRIEVABLE MONITORED CONTAINMENT STRUCTURES (RMCS)

Retrievable storage is a concept utilizing above ground landfill design technology to develop a vault for hazardous waste storage. Waste can be retrieved more easily when recovery, destruction, or detoxification proves technically or economically feasible. RMCS also include above ground vaults for water storage associated with a process.

3.2 STOCKPILE/WASTE PILE

Stockpiling is a technology most often associated with mining and involves the collection and storage of material in above ground mounds. Stockpiles can be designed and managed to control leachate and runoff. They are often used for temporary storage of bulk waste during site remediation, pending treatment and/or ultimate disposal.

3.3 SURFACE IMPOUNDMENT

A surface impoundment is a natural topographic depression, manmade excavation, or diked area formed primarily of earthen materials which holds an accumulation of liquids or sludges containing free liquids. Minimum technical performance standards such as a double-liner, leachate collection, and monitoring exist for surface impoundments containing hazardous waste.

3.4 DRUMS/CONTAINERS/TANKS

A drum is a cylindrical shipping container for solids and liquids having a capacity of 12 to 110 gallons (gal). A drum for storage of hazardous waste material must achieve minimum U.S. Department of Transportation (DOT)

standards. Drums can be metal, fiberboard or plastic, depending on compatibility and structural requirements. Containers also include structural holders of material, like roll-off containers and dumpsters.

A tank system includes a container and any associated equipment, pipes, pumps, or valves. A hazardous waste tank must provide secondary containment, vent lines, monitoring equipment, leak detection, and adequate corrosion control compatibility in addition to structural strength. A tank can be underground or above ground, but is a stationary device designed to contain an accumulation of hazardous waste, and is constructed primarily of nonearthen materials such as concrete, steel, plastic, or fiberglass.

4.0 DIRECT TREATMENT

This section describes direct methods applicable for treating aqueous, gaseous, and solid waste streams. Many of the treatment methods described in this section are widely used in industrial waste treatment applications.

Waste streams resulting from the cleanup of hazardous waste sites vary widely with respect to volume, physical condition, and type of contaminants. The major sources of wastes include:

- o Contaminated soils/solids excavated from disposal areas;
- o Rubble from building demolition;
- o Leachate plumes which have been pumped to the surface or otherwise collected;
- o Contaminated sediments/liquids generated during dredging operations; and
- o Highly concentrated waste streams generated from waste treatment processes.

Because these waste streams are so diverse a variety of treatment processes will have potential application to hazardous waste site cleanup. This section addresses those processes considered applicable for hazardous waste site remediation. Rarely will any one unit treatment process be sufficient for waste treatment. Therefore, the following discussions include information on unit treatment processes that are frequently used in combination, and pretreatment requirements for effective use of each treatment process.

4.1 PHYSICAL/CHEMICAL TREATMENT

4.1.1 WASHING

In washing, soil or solid wastes are excavated and treated at the surface in a washer. The extractant solutions used in the washer include water, surfactants, acids or bases, chelating agents, and oxidizing and reducing agents. All resulting wastewater must be further treated by other methods.

Contaminants that are amenable to water flushing can be identified according to their soil/water partition coefficients which can be estimated from

octanol/water partition coefficients. (K_{OW}<1000 indicate that the compound is environmentally soluable).

4.1.2 VACUUM DUSTING

Vacuum dusting is the removal of dust and debris from a contaminated surface by air suction. It can be applied in the decontamination of structures where contaminants may be concentrated in surface dust. Vacuum dusting is most effective when used in conjunction with other treatment processes which chemically or physically loosen surface particulates.

4.1.3 HYDRAULIC SCOUR

Hydraulic scour uses water jets at high pressures, (500 to 20,000 psi), to impact surfaces for removal of contaminants. Surface debris and water are then collected and decontaminated. Surfactants, abrasives, and heat may complement the process. This offers a relatively inexpensive, nonhazardous surface decontamination technique using off-the-shelf equipment. Many manufacturers produce a wide range of hydroblasting systems and high-pressure pumps. Hydraulic scour may not effectively remove contaminants that have penetrated the structural material beyond the surface. Large amounts of water must be collected and treated.

4.1.4 MECHANICAL SCOUR

Sandblasting or gritblasting is a mechanical scour surface removal technique in which an abrasive such as sand or steel pellets is used to uniformly remove building material layers containing contaminants. Sandblasting is a widely used surface removal technique and can simultaneously remove paint and contaminants near the surface. Large amounts of contaminated dust and debris are generated by this process.

4.1.5 ACID ETCH

This decontamination process applies acid or bleach to a surface to promote corrosion. Neutralization and removal of the surface layer follows. The debris are collected and decontaminated. The acid itself may cause decomposition of the contaminant. This application is a hazardous operation requiring large quantities of acidic hazardous materials and skilled labor.

4.1.6 DRILL AND SPALL

The drill and spall technique is capable of removing approximately six inches of surface layer from concrete or similar materials. The technique consists of drilling holes 1 to 1.5 inches in diameter approximately three inches deep into the surface. The spalling tool bit is inserted into the hole and hydraulically spreads to spall the contaminated concrete. This application is effective on large-scale jobs, but is effective only as a surface treatment of concrete. Substantial amounts of contaminated debris require processing.

4.1.7 SCARIFICATION

Scarifier techniques remove approximately one inch of surface layer from concrete or similar materials. The scarifier tool consists of pneumatically operated piston heads that strike a surface, causing concrete to chip off a structure. The piston head consists of multipoint tungsten carbide bits. This method of decontamination can achieve a deeper removal of surface contaminants and has greater applicability compared with most surface removal techniques. Substantial amounts of contaminated debris are generated, requiring further processing.

4.1.8 STEAM CLEANING

Steam cleaning physically extracts contaminants from building materials and equipment surfaces. The steam is applied by hand-held wands or automated systems, and the condensate is collected for treatment. Steam cleaning is a relatively simple technique. Depending on the contaminant, thermal decomposition and/or hydrolysis may occur. This technique is only effective for surface decontamination.

4.1.9 SEALANT/ENCLOSURE

In this technique, contaminants or contaminated structures are physically separated from building occupants or the ambient environment by a barrier. An encapsulating or enclosing physical barrier can consist of a variety of sealants, resins, or concrete. Acting as an impenetrable shield, this barrier keeps contaminants inside and away from clean areas.

4.1.10 ELECTROPOLISHING

Electropolishing is a physical abrasive concept commonly using an electrochemical process for decontamination. A contaminated metal object serves as the anode in an electrolytic cell. The passage of electric current results in the anodic dissolution of the surface material and with proper operating conditions, a progressive smoothing of the surface. Contaminants on the surface are entrapped within surface imperfections or are removed into the electrolyte by this surface dissolution process. The production of a polished surface also facilitates the removal of residual electrolyte.

4.1.11 ULTRASOUND

Ultrasonic cleaning is a surface scrubbing technique in which small equipment is removed and loaded into ultrasonic cleaning tanks. Specially designed scrubbers then are used to clean walls and floors. An ultrasonic cleaning system typically consists of an ultrasonic generator, a transducer, a cleaning tank, a liquid-coupling agent solvent, and a heater. The warm liquid coupling agent serves to transmit this energy to the object to be cleaned. The wave cycle causes the liquid to cavitate and implode, creating minute quantities of energy with tremendous localized force. Pressures and temperatures are approximately 10^4 psi and 104 ^{o}C, respectively. These imploding cavities scrub the surface being decontaminated, causing spalling and descaling. This process is potentially applicable to all building materials but only as a surface removal technique. The cleaning liquid and removed surface must be decontaminated and disposed.

4.1.12 SOLIDIFICATION AND STABILIZATION

Solidification and stabilization are terms used to describe treatment systems that accomplish one or more of the following objectives:

- Improve waste handling or other physical characteristics of the waste;
- Decrease the surface area across which transfer or loss of contained pollutants can occur; and/or
- Limit the solubility or toxicity of hazardous constituents.

Solidification is used to describe processes where these results are obtained primarily, but not exclusively, by production of a monolithic block of waste with high structural integrity. The contaminants do not necessarily interact chemically with the solidification reagents, but are mechanically locked within the solidified matrix. Contaminant loss is minimized by reducing the surface area.

Stabilization methods usually involve the addition of materials that limit the solubility or mobility of waste constituents even though the physical handling characteristics of the waste may not be improved. Methods involving combinations of solidification and stabilization techniques are often used.

4.1.12.1 Sorption

Sorbents include a variety of natural and synthetic solid materials used to eliminate free liquid and improve waste handling characteristics. Commonly used natural sorbent materials include fly ash, kiln dust, vermiculite, and bentonite. Synthetic sorbent materials include activated carbon which sorbs dissolved organics, Hazorb which sorbs water and organics, and Locksorb which is reportedly effective for all emulsions.

Some sorbents have been used to limit the escape of volatile organic compounds. Sorbents can be useful in waste containment when used to modify the chemical environment and maintain the pH and redox potential to limit solubility. Although sorbents prevent drainage of free water, they do not necessarily prevent leaching of waste constituents, and secondary containment is generally required.

The quantity of sorbent material necessary for removing free liquid varies widely depending on the nature of the liquid phase, the solids content of the waste, the moisture level in the sorbent, and the occurrence of any chemical reactions that absorb liquids. It is generally necessary to determine the quantity of sorbent needed on a case-by-case basis.

4.1.12.2 Lime-Fly Ash Pozzolan Process

Pozzolanic materials are those that set to a solid mass when mixed with

hydrated lime. Natural pozzolanic materials called pozzolana consist of either volcanic lava masses called tuff or deposits of hydrated silicic acid of mostly organic origin, such as diatomaceous earth. Artificial pozzolana are materials such as blast-furnace slag, ground brick, and some fly ashes from powdered coal furnaces.

Solidification and stabilization of waste using lime and pozzolanic material requires mixing with a carefully selected, reactive fly ash or other pozzolanic material, to a pasty consistency. Hydrated lime, calcium hydroxide, is blended into the waste-fly ash mixture. Typically, 20 to 30 percent lime is needed to produce a strong pozzolan. The resulting moist material is packed or compressed into a mold to cure or is placed in the landfill and rolled.

Standard testing systems and standard specifications exist for pozzolanic materials, especially for fly ash. The specifications take into account the chemical composition (percentage SiO_2, SO_3, and moisture), and physical properties, (fineness, pozzolanic activity with lime, and specific gravity).

4.1.12.3 Pozzolan-Portland Cement Process

A wide variety of treatment processes incorporate Portland cement as a binding agent. Pozzolanic products are those materials with fine-grained, noncrystalline and reactive silica which are frequently added to Portland cement to react with any free calcium hydroxide and thus improve the strength and chemical resistance of the concrete-like product. In waste solidification, the pozzolanic materials such as fly ash are often used as sorbents. Much of the pozzolan in waste processing may be inactivated by the waste. Any reaction that does occur between the Portland cement and free silica from the pozzolan adds to the product strength and durability. The types of Portland cement used for solidification can be selected so as to emphasize a particular cementing reaction.

Cement/fly ash processes typically are used in conjunction with sorbents or other additives which decrease the loss of specific hazardous materials from the rather porous, solid products. Such adaptations of the technology are

also often necessary because some materials inhibit the binding action in Portland cement.

4.1.12.4 Thermoplastic Microencapsulation

Thermoplastic microencapsulation has been successfully used in nuclear waste disposal and can be adapted to special industrial wastes. This technique for isolating waste involves drying and dispersing it through a heated, plastic matrix. The mixture is then permitted to cool to form a rigid but deformable solid. In most cases a fiber or metal drum is used to contain the material for transport. The most common material used for waste incorporation is asphalt, although other materials such as polyethylene, polypropylene, wax, or elemental sulfur can be employed for specific wastes.

4.1.12.5 Macroencapsulation

Macroencapsulation systems contain potential pollutants by bonding an inert coating or jacket around a mass of cemented waste or by sealing them in polyethylene-lined drums or containers. This type of waste stabilization is often effective when others are not because the waste block jacket or coating completely isolates the waste from its surroundings. The waste may be stabilized, microencapsulated, and/or solidified before macroencapsulation so that the external jacket becomes a barrier designed to overcome the shortcomings of available treatment systems.

4.1.12.6 Glassification

Glassification of wastes involves combining the waste with required additives to form a "melt" of molten glass at a predetermined temperature. This melt is cooled into a stable, noncrystalline solid which may be amenable to landfilling as a non-hazardous substance, depending on the original waste composition and process performance.

4.1.12.7 Down Draft Sintering

Sintering consists of a controlled liquification of the surface of particles within a mass followed by controlled cooling of the mass so that the particles adhere together and form a clinker. The particles are thus encapsulated in a layer of solidified vitreous slag. This process is used in the metallurgical industry to prepare various ores for further treatment.

This process would be applicable to soils contaminated with a combination of organics, inorganic salts, and metals. The organics would be incinerated during the fusion stage. Volatile metals such as mercury and arsenic would be driven off and collected in the off gas treatment system. Inorganic salts and heavy metals would be slagged and contained in the sinter as solid solutions.

4.1.12.8 Polymerization

Polymerization involves injection of a catalyst into a contaminated media to cause transformation of an organic monomer, such as, styrene, vinyl chloride, isoprene, methyl methacrylate, and acrylonitrile. The polymerization reaction transforms the once fluid substance into a gel-like, nonmobile mass.

4.1.13 ABSORPTION

Absorbents may be clay/silicate-based, filter-media used to remove oily organic contaminants from wastewater. It has been successful as a filtering media prior to activated carbon adsorption in removing waste particles that tend to plug the filters. It is also effective in oil/water separation processes such as dissolved air flotation and gravity separators.

4.1.14 VOLATILIZATION (NATURAL)

Natural volatilization is the mechanism whereby contaminated materials are exposed to conditions that favor volatilization of organic contaminants. No external influences, such as heat, are introduced.

4.1.15 MAGNETIC SEPARATION

Magnetic separation techniques have been used since the nineteenth century to remove tramp iron and concentrate iron ores. A variety of conventional magnetic separation devices are in wide use today. These devices generally separate relatively coarse particles of highly magnetic-material containing large amounts of iron from non-magnetic media.

Energy requirements may be relatively large, especially if high magnetic fields are required.

The use of magnetic separation or filtration in water treatment may be accomplished in two ways depending on the nature of the contaminants in the water. For waters contaminated by magnetic suspended solids, such as steel mill waste waters and the corrosion products of boiler waters, magnetic filtration may be used alone to effectively remove these particles.

Magnetic separation may also be used to remove non-magnetic contaminants from water. This is accomplished by binding finely divided seed particles to the non-magnetic contaminants. Binding is accomplished by either adsorption of the contaminant to magnetic seed or chemical coagulation.

The applications of magnetic separation to water treatment include the removal of suspended solids, heavy metals, bacteria, algae, virus, dissolved phosphorus, and color turbidity.

4.1.16 DEWATERING

Dewatering is a physical unit operation used to reduce the moisture content of slurries or sludges to facilitate handling and prepare the materials for final treatment or disposal. Methods to dewater slurries or sludges include gravity thickeners, centrifuges, filters, belt presses, drying beds, and vacuum filtration units. Selection of the most appropriate method depends on slurry volume, solids content, land availability, and the degree of dewatering required prior to treatment or disposal. Although several dewatering methods are extremely effective in removing water, the solids are often not sufficiently dry to meet requirements for final disposal and require further treatment to fix or solidify wastes. Water generated during dewatering generally contains hazardous constituents and several hundred to several thousand milligrams per liter (mg/L) suspended solids and requires additional treatment. Water from dewatering can generally be treated in conventional wastewater treatment systems.

4.1.17 SEDIMENTATION

Sedimentation is a process using gravity to remove suspended solids from an aqueous waste stream. The fundamentals of a sedimentation process include:

- A basin or container of sufficient volume to maintain the liquid to be treated;

- o A means of directing the liquid to be treated into and out of a basin in a manner conducive to settling; and
- o A means of physically removing the settled particles from the liquid or removing liquid from the settled particles.

Sedimentation can be accomplished as either a batch or continuous process in lined impoundments, conventional settling basins, clarifiers, and high-rate gravity settlers. Modified above ground swimming pools often have been used for sedimentation in temporary, short-term treatment systems at hazardous waste sites. In sedimentation ponds, the liquid is decanted as the particles accumulate on the bottom of the pond. Backhoes, draglines, or siphons are used periodically to remove settled solids.

Sedimentation is commonly applied to wastewaters with high suspended solid loadings including surface runoff, collected leachate or landfill toe seepage, dredge slurries, and effluents from biological treatment and precipitation/flocculation.

4.1.18 FLOTATION/SEPARATION

Gravity separation of oil is a physical treatment in which the oil is permitted to separate from water in a tank. Gravity separators are primarily used to treat two-phased aqueous wastes. A typical application would be separation of free gasoline or fuel oil from a contaminated aquifer. Gravity separation has also been used to separate polychlorinated biphenyl (PCB) oils from contaminated ground water. For efficient separation, the nonaqueous phase should have a significantly different specific gravity than water and should be present as a nonemulsified liquid. Emulsion between water and oil is common, and an emulsion-breaking chemical frequently must be added to the waste for efficient treatment.

Gravity separation offers a straightforward, effective means of phase separation provided the oil and water phases separate adequately within the residence time of the tank. Simple, readily available equipment can be used and operational requirements are minimal. If emulsion-breaking chemicals

must be added to promote oil-water separation, laboratory tests should be periodically conducted to ensure adequate dosing. Consideration must also be given to the disposal of the extracted waste constituents collected.

Flotation is a physical treatment process that uses air to float sludge, oil, or other suspended solids less dense than water and allow separation from the water phase. In a DAF system, a recycled subnatant flow is pressurized from 30 to 70 pounds per square inch (psi), then saturated with air in a pressure tank. The pressurized effluent is then mixed with the influent and subsequently released into the flotation tank. The excess dissolved air then separates from solution, and the small rising gas bubbles attach to particles in the wastewater. Flotation aids in the form of polyelectrolytes often are used. The floated agglomeration of material rises to the surface to form a froth and is removed by mechanical scraper.

4.1.19 FILTRATION/SEPARATION

Filtration/separation physically segregates particles from fluid. Filtration/separation can remove large suspended solids down to small molecules.

4.1.19.1 Reverse Osmosis

Osmosis is the spontaneous flow of water from a dilute solution through a semipermeable membrane to a more concentrated solution. Reverse osmosis (RO) applies sufficient pressure to the concentrated solution to overcome osmotic pressure and force the net flow of water through the membrane towards the dilute phase.

This allows concentration of solute impurities in a circulating system on one side of the membrane while relatively pure water is transported through the membrane. The membrane, membrane support structure, containing vessel, and high-pressure pump are the basic components of an RO unit. The membrane and membrane support structure are the most critical elements.

RO is used to increase the concentration of dissolved solids, and miscible liquids. In treatment of hazardous waste contaminated streams, use of RO would be limited primarily to polishing low-flow streams containing

highly toxic contaminants. Good removal can be achieved for high molecular weight organics and charged anions and cations. Multivalent ions are treated more effectively than are univalent ions. Recent advances in membrane technology have made it possible to remove such low molecular weight organics as alcohols, ketones, amines, and aldehydes.

RO systems are compact, and the operation of the system is relatively simple. Because RO systems are modular in design, scheduled maintenance can be performed without shutting down the plant. Large changes in certain influent properties can foul the RO membrane or necessitate frequent replacement. Pretreatment before the membrane serves to avoid these complications. A major disadvantage of RO is the concentrated waste stream, which must be treated or disposed.

4.1.19.2 Filtration

Filtration is a physical process whereby suspended solids are removed from solution by forcing the fluid through a porous medium.

4.1.19.3 Ultra-Filtration

Ultra-filtration involves the use of membranes to separate molecules of different sizes and structures. The solution is forced through the membranes under relatively high pressure. Ultrafiltration is generally limited to treatment of organic compounds with molecular weights greater than 500 Atomic Mass Units (AMUs).

4.1.20 DIALYSIS

So far, industrial application of dialysis has been directed primarily toward such operations as caustic recovery in the rayon industry, separation of sulfuric acid from copper and other metals, and the separation of sugars from dextrins. In each of these cases dialysis proceeds in response to a difference in chemical potentials of the solutes across the membrane. In dialysis, a solution which contains a permeating species and is separated from a solution at lower concentration, loses solute through the membrane until the activity of the solute is the same on both sides of the membrane. Energy requirements are low being limited to the pumping of feed and wash water.

Dialysis is an advanced waste treatment process for the removal of selected organics and metallic ions from industrial waste. This process can be both technically and economically feasible when removal of the membrane permeant is supported by special schemes such as acid and bases conjugation, complexing, or pervaporation, rather than reliance upon simple dilution to maintain the osmotic gradient.

4.1.21 ELECTRODIALYSIS

In the electrodialysis process, ionic components of a solution are separated through the use of semipermeable ion-selective membranes. Application of an electrical potential between the two electrodes causes an electric current to pass through the solution, which, in turn causes a migration of cations toward the negative electrode and a migration of anions toward the positive electrode. Because of the alternate spacing of cation-and anion-permeable membranes, cells of concentrated and dilute salts are formed.

This process may be operated in either a continuous or a batch mode. The units can be arranged either in parallel to provide the necessary hydraulic capacity or in series to effect the desired degree of demineralization. Makeup water, usually about 10 percent of the feed volume, is required to wash the membranes continuously. A portion of the concentrate stream is recycled to maintain nearly equal flowrates and pressures on both sides of each membrane. Sulfuric acid is fed to the concentrate stream to maintain a low pH and thus minimize scaling.

Problems associated with the electrodialysis process for wastewater renovation include chemical precipitation of salts with low solubility on the membrane surface and clogging of the membrane by the residual colloidal organic matter in wastewater treatment plant effluents. To reduce membrane fouling, activated-carbon pretreatment, possibly preceded by chemical precipitation and some form of multimedia filtration, may be necessary.

4.1.22 SOLVENT EXTRACTION

Solvent extraction involves the use of an organic solvent to extract contaminants from liquid media. Depending on the solvent-agent

compatibility, the process may be an efficient removal system. Also, in most solvent extraction systems the spent solvent is regenerated and recycled, so that the only material to be disposed of is the "neat" toxic material which has been extracted from the waste, and the "clean" residue. This technology has been demonstrated full-scale at a hazardous waste site in Savannah, Georgia.

4.1.23 STRIPPING

4.1.23.1 Air

Air stripping is a mass transfer process in which volatile contaminants in water are transferred to gas. Air stripping is generally accomplished in a packed tower equipped with an air blower. The packed tower works on the principle of countercurrent flow, where water flows down through the packing while air flows up and is exhausted through the top. Volatile, soluble components with an affinity for the gas phase are stripped from the aqueous stream.

Air stripping equipment is relatively simple, startup and shutdown can be accomplished quickly, and the modular design of packed towers makes air stripping well suited for hazardous waste site applications. It has been used primarily for treatment of low concentrations of volatiles or as a pretreatment step prior to activated carbon.

An important consideration in applying air stripping for removal of volatile contaminants is potential air quality impacts. Exhaust gases may require vapor phase treatment.

4.1.23.2 Steam

Steam stripping can also be used to remove organics from aqueous wastes. Steam stripping is essentially a continuous fractional distillation process carried out in a packed or tray tower. Clean steam provides direct heat to the tower and aqueous waste. The resulting effluent streams include a contaminated steam condensate, and stripped aqueous. The contaminated steam condensate stream can be processed to recover or concentrate the organic wastes.

4.1.24 STEAM DISTILLATION

Distillation involves evaporation of the liquid; transport of the vapor away from the liquid; and vapor condensation. The distillation process depends on the differences in vapor pressure of the mixture components to accomplish separation, so some compounds such as salts are easily separated.

Evaporation occurs when the partial pressure of the component in the gas above the liquid is less than the equilibrium vapor pressure of the component at the temperature and pressure of the liquid surface. Condensation occurs when the partial pressure of a vapor component is greater than the vapor pressure of the component at the temperature and pressure of the vapor. Condensation can be induced by cooling or compressing the vapor. Because the heat of vaporization is released when the vapor condenses, the rate of condensation can be controlled by the cooling rate. A typical process type is a thin-film evaporator.

4.1.25 ADSORPTION

Adsorption is the adherence of one substance to the surface of another by physical and chemical processes. Treatment of wastestreams by adsorption is essentially a process of transferring and concentrating contaminants from one medium to another.

4.1.25.1 Activated Carbon

The process of adsorption onto activated carbon involves contacting a waste stream with the carbon, usually by flow through a series of packed-bed reactors. The activated carbon selectively adsorbs hazardous constituents by a surface attraction phenomenon in which organic molecules are attracted to the internal pores of the carbon granules.

Adsorption depends on the strength of the molecular attraction between adsorbent and adsorbate, molecular weight, type and characteristic of adsorbent, electrokinetic charge, pH, and surface area.

Once the micropore surfaces are saturated with organics, the carbon must either be disposed or thermally regenerated. The time to reach "breakthrough" or exhaustion is the single most critical operating

parameter. Activated carbon is a well-developed technology which is widely used in the treatment of hazardous waste streams. It is especially well suited for removal of mixed organics from aqueous wastes.

As carbon adsorption is essentially an electrical interaction phenomenon, the polarity of the waste compounds will largely determine the effectiveness of the adsorption process. Highly polar molecules cannot be removed effectively by carbon adsorption. Another factor to consider in determining the likely effectiveness of carbon adsorption is aqueous solubility. The more hydrophobic a molecule is, the more readily the compound is adsorbed. Low-solubility humic and fulvic acids which may be present in the ground water sorb to activated carbon more readily than most waste contaminants which results in rapid carbon exhaustion.

4.1.25.2 Activated Alumina

Similar to activated carbon, activated alumina can selectively adsorb certain constituents within an aqueous waste stream. Sharply decreased removal efficiency or "breakthrough" will occur when the alumina has become saturated after which it can be regenerated. Common applications are for fluoride and/or arsenic removal. The process is sensitive to pH. Treatment systems generally consist of a series of packed columns which can be operated in the upflow or down-flow mode.

4.1.25.3 Ion Exchange And Sorption Resins

Ion exchange is a process whereby certain ions are removed from the aqueous phase by being exchanged with more desirable ions from the ion exchange material. Modern ion exchange resins are primarily synthetic organic materials containing ionic functional groups to which exchangeable ions are attached. These synthetic resins can tolerate a range of temperature and pH conditions, exhibit a high exchange capacity, and can be selective toward specific ions. Exchangers with negatively charged sites are cation exchangers because they accept positively charged ions. Anion exchangers have positively charged sites and, consequently, accept negative ions. The exchange reaction is reversible and concentration dependent, and it is therefore possible to regenerate the exchange resins for reuse.

Ion exchange is used to remove a broad range of ionic species from water including:

- Various metallic elements when present as soluble species, either anionic or cationic;
- Inorganic anions (halides, sulfates, nitrates, cyanides);
- Organic acids (carboxylics, sulfonics, and some phenols), at a pH sufficiently alkaline to donate the ions; and
- Organic amines when the solution acidity is sufficient to form the corresponding acid salt.

Sorptive resins are also available for removal of organics where the removal mechanism is one of sorption rather than ion exchange. Sorptive resins can remove a wide range of polar and nonpolar organics.

4.1.25.4 Molecular Sieve

Molecular sieves are an important class of synthetic adsorbents. Molecular sieves are aluminosilicates that have undergone heating to remove water of hydration. They possess high porosity, with pores of uniform size and essentially molecular dimensions. They adsorb small molecules only, are selective on molecular shape, and have a particular affinity for unsaturated and polar molecules. Molecular sieves are used primarily in gas treatment.

4.1.26 NEUTRALIZATION

Neutralization consists of adding acid or base to a waste to adjust its pH to near neutrality. The most common system for neutralizing acidic or basic waste streams utilizes a multiple compartmental basin usually constructed of concrete. This basin is lined with acid brick or coated with a material resistant to the expected environment.

Neutralization of hazardous wastes has the potential of producing air emissions. Acidification of streams containing certain salts, such as sulfide, will produce toxic gases. Feed tanks containing acid should be totally enclosed to prevent release of fumes. Adequate mixing must be provided to disperse the heat of reaction if concentrated wastes are being treated. The process should be controlled from a remote location if possible.

4.1.27 PRECIPITATION/FLOCCULATION

Precipitation is a physiochemical process whereby some or all of a substance in solution is transformed into a solid phase. It is based on alteration of the chemical equilibrium relationships affecting the solubility of inorganic species. Removal of metals as hydroxides or sulfides is the most common precipitation application in wastewater treatment. Generally, lime or sodium sulfide is added to the wastewater in a rapid mixing tank along with flocculating agents. The wastewater flows to a flocculation chamber in which adequate mixing and retention time is provided for agglomeration of precipitate particles. Agglomerated particles are separated from the liquid phase by settling in a sedimentation basin.

Flocculation describes the process by which small unsettleable particles suspended in a liquid medium agglomerate into larger, settleable particles. The mechanisms by which flocculation occurs involve surface chemistry and particle charge phenomena. Typically, chemicals used to cause flocculation include alum; lime; various iron salts, such as, ferric chloride and ferrous sulfate; and organic flocculating agents, referred to as poly-electrolytes.

4.1.28 CHELATION

The use of chelating agents also may be an effective means of immobilizing metals, although considerable research is needed in this area. Depending on the specific chelating agent, stable metal chelates may be highly mobile or may be strongly sorbed to the soil. Tetran is an example of a chelating agent that is strongly sorbed to clay in soils.

4.1.29 HYDROLYSIS

Hydrolysis involves the displacement of a hydroxyl group in a chemical substance by water. The rate of hydrolysis is dependent on temperature, solvent composition, catalyst, and pH. Cleavage rates of organic molecules acid/base-catalyzed hydrolysis can be accelerated by pH adjustment.

4.1.30 OXIDATION/REDUCTION

Oxidation/reduction (redox) reactions are those in which the oxidation state of at least one reactant is raised while that of another is lowered.

Oxidation reactions are performed using simple, readily available equipment. Only storage vessels, metering equipment, and contact vessels with agitators are required. However, implementation can be complicated because every redox reaction system must be designed for the specific application. Laboratory and/or pilot-scale testing are essential to determine the appropriate chemical feed rates and reactor retention times in accordance with reaction kinetics. Redox has not been widely used in treating hazardous waste streams.

4.1.30.1 Chemical

A major consideration in electing to use oxidation technology is that the treatment chemicals are potentially hazardous, and great care must be taken in their handling. In some cases, undesirable byproducts may be formed as a result of oxidation. For example, addition of chlorine can result in formation of bioresistant end products which can be odorous and more toxic than the original compound. The possibility of this undesirable side reaction needs to be considered when using chlorine for oxidation of wastewaters.

Chemical reduction involves addition of a reducing agent that lowers the oxidation of a substance to reduce toxicity or solubility or to transform it to a form which can be more easily handled.

4.1.30.2 Electrolytic

In this process, cathodes and anodes are immersed in a tank containing a waste to be oxidized, and a direct electrical current is imposed on the system. During the decomposition, positive cations, usually metals, are deposited or plated on a cathode.

4.1.30.3 Ultraviolet - Ozone Treatment

This process is an enhanced oxidation which utilizes an ultraviolet energy source. This process has the added advantage of breaking-up chemical compounds that would otherwise not be addressed by ozone alone.

4.1.31 CHEMICAL DEHALOGENATION

4.1.31.1 Alkali Metal Dehalogenation

Sodium metal has been used for dechlorinating PCB's in transformer oil. This technology may be applicable for dehalogenating RMA contaminants.

4.1.31.2 Alkali Metal and Polyethylene Glycol Dechlorination (A/PEG)

In the alkali metal/polyethylene glycol (A/PEG) reagents, the alkali metal ion is held in solution by the large polyethylene glycolate anion. PCBs and other halogenated molecules are uniquely soluble in A/PEG reagents. These qualities combined to give a single-phase system in which the high concentration of anions readily displaces the halogen atoms on halogenated molecules. The reaction of halogenated aromatics with PEGs results in a substitution of the PEG for the chlorine atom to form a PEG ether. The PEG ether, in turn may then decompose to phenol.

4.1.32 ULTRAVIOLET PHOTOLYSIS

Photochemistry has long been utilized as a low temperature method for initiating synthetic chemical reactions, such as, chlorination or polymerization. In the last decade, the ability of photochemistry to initiate degradation reactions to destroy environmentally hazardous materials has been recognized.

Essentially, the photochemical reaction is initiated by the absorption of ultraviolet light. A reaction agent is added to optimize the photochemical reaction and degradation of the contaminant molecular bonds.

4.1.33 ELECTRON BEAM

Electron beam treatment is a photochemical process in which chemical decomposition is brought about by exposure to beta particles. Electron beam treatment has been limited to sludge disinfection, although a few laboratory studies of hazardous chemical degradation have been performed.

4.1.34 GAMMA IRRADIATION

Gamma irradiation is similar to electron beam treatment and ultraviolet photolysis. The energy-carrying species are gamma particles formed by radioactive decay of Cesium-137 or Cobalt-60. Gamma particle penetration is nearly two orders of magnitude greater than that of beta particles. This penetration allows reactor designs with longer radiation paths but also requires considerable shielding. The production of gamma rays by radioactive decay is a continuous process and cannot be moderated or stopped.

Reactors for disinfection of both dry and liquid sludges have been designed. Some laboratory work has been performed on hazardous materials. Oxidizing and reducing agents would probably aid hazardous waste decomposition.

4.1.35 SCRUBBING

Wet collection devices for fumes, mists, and suspended dusts are called scrubbers. This class of pollution control equipment collects particulates by direct contact with a liquid, usually water. There are a multitude of scrubber designs on the market; most of them can be grouped according to the liquid contacting mechanism used. In addition, scrubbers can be classified as low-, moderate-, or high-energy units.

4.1.36 PRECIPITATION

The process of electrostatic precipitation involves the ionization of the contaminated air flowing between electrodes; the charging, migration, and collection of the contaminants (particles) on oppositely charged plates; and the removal of the particles from the plates.

The electrostatic precipitator is unique among air pollution control devices in that the forces of collection act only on the particles and not on the entire air stream. The air flows through the precipitator, but the particles are left behind on the charged plates. This phenomenon typically results in a high collection of efficiency with a very low air pressure drop. The material left on the plates is washed or knocked off and is collected in the bottom of the precipitator. Electrostatic precipitation only works if particles are of a composition that can accept a charge.

4.1.37 FILTRATION

Filtration, i.e., fabric filtration, is a well known and accepted method for separating dry particles from a gas stream, usually of air or combustion gases. In fabric filtration, the dusty gas flows into and through a number of filter bags placed in parallel, leaving the dust retained by the fabric. The fabric itself does some filtering of the particles. However, the fabric is more important in its role as a support medium for the layer of the dust that quickly accumulates on it. The dust layer is responsible for the highly efficient filtering of small particles for which baghouses are known. Extended operation of a baghouse requires that the dust be periodically cleaned off the cloth surface and removed from the baghouse. The three common types of baghouses, classified by the method used for cleaning the dust from the bags, are reverse-air, shaker, and pulse-jet baghouses. The annualized cost of owning and operating a fabric filter baghouse can be very high because of power requirements.

4.1.38 AFTERBURNERS

One method of pollution control which can be applied broadly to volatile organic compounds (VOCs) is incineration. Incineration can be used for odor control, to destroy a toxic compound, or simply reduce the quantities of photochemically reactive VOCs released to the atmosphere. Thermal VOC incinerators are also called afterburners. The main advantage of incineration is its potential for very high efficiency. If held for a sufficient length of time at a sufficient temperature, organics can be oxidized to any desired degree of completeness. The process design for an afterburner involves specifying a temperature of operation along with a desired residence time, and then sizing the device to achieve the desired residence time and temperature with the proper flow velocity. The main disadvantage of incineration is the high fuel cost. Also, some of the products of combustion of certain pollutants are themselves pollutants. For example, when a chlorinated hydrocarbon is burned, HCl or Cl_2 or both will be emitted. Depending on the amounts of these by-product pollutants, additional controls might be required.

4.1.39 GAS-PHASE CARBON

The removal of low-concentration gases and vapor form an exhaust stream by the adherence of these materials to the surface of a porous solid is an example of a practical application of adsorption. Gas adsorption is used for industrial applications such as odor control; the recovery of volatile solvents such as benzene, ethanol, trichloroethylene, freon, and so forth; and the drying of process gas streams. The adsorbents used for air pollution control include activated carbon, alumina, bauxite, and silica gel. But, activated carbon is by far the most frequently used adsorbent, and has virtually displaced all other materials in solvent recovery systems.

Gas-phase carbon systems generally use fixed beds, and the design and operation of these systems involves heat and mass transfer, fluid dynamics, process control, and chemical analysis. Because of the variety of applications and the differences in design, adsorber costs are more difficult to estimate than other pollution control systems. The major utility costs associated with adsorber operation are steam--most fixed-bed carbon systems are designed for steam regeneration--electricity, and cooling-water costs.

4.2 BIOLOGICAL TREATMENT

The function of biological treatment is to remove organic matter from the waste stream through microbial degradation. The most prevalent form of biological treatment is aerobic. There are a number of biological treatment processes which may be applicable to treatment of aqueous wastes from hazardous waste sites: conventional activated sludge; various modifications of the activated sludge process including pure oxygen activated sludge, extended aeration, and contact stabilization; and, fixed film systems that include rotating biological discs and trickling filters.

4.2.1 AEROBIC

Remediation of hydrocarbon contamination was conducted using a treatment approach involving stimulating the indigenous microorganisms through the delivery of nutrients and air to the subsurface. Considerable developments have been made subsequently, and many treatment approaches have been used successfully to enhance biodegradation in contaminated zones. Specialized

microorganisms, either adapted strains or genetically altered strains, have been used, and hydrogen peroxide or ozone appear to be feasible alternatives to air or pure oxygen as an oxygen source. Biological degradation is currently being tested at hazardous waste disposal sites containing a complex range of organics.

4.2.1.1 Composting

Composting is the controlled decay of organic matter in a warm, moist environment by the action of biological organisms. The environment may be aerobic or anaerobic. The operation has historically been used primarily for the treatment of nonhazardous solid waste.

Treatability studies on biotransformation of complex organics suggest nerve agents and chlorinated hydrocarbons can be degraded and completely detoxified by microbial systems. At high concentrations, almost all organic materials are toxic and inhibit microbial activity.

4.2.1.2 Land Application

Land application is used for the ultimate disposal of liquids or sludges. This process is a biological soil adsorption mechanism. Land application is popular as a disposal method because it is simple. Waste application can have benefits as a soil conditioner and/or nutrient supplement for a cover crop. Land application has the ability to filter, buffer, absorb, and chemically and biologically react with sludge constituents. However, toxics may pass through the soil unchanged and contaminate surface or ground water. Accumulation of toxics in the soil and odor are potential problems.

4.2.1.3 Land Farming

Land farming involves tilling of the soil in-place to enhance microbial degradation of contaminants in soil. Through volatilization and biodegradation, organic contaminant levels are decreased in the near-surface soils.

4.2.1.4 Bio-Uptake

An additional type of bio-uptake involves agricultural crops which are planted in zones with near surface contamination. Pesticide levels have been known to decrease in soils after continued agricultural use.

4.2.1.5 Bioreactor

Biodegradation is a technique for treating zones of contamination by microbial degradation. The basic concept involves altering environmental conditions to enhance microbial catabolism or co-metabolism of organic contaminants, resulting in the breakdown and detoxification of those contaminants. The technology has been developed rapidly over recent years, and bioreclamation appears to be one of the most promising treatment techniques.

Considerable research conducted over the past several decades has confirmed that microorganisms are capable of breaking down many organic compounds considered to be environmental and health hazards at spill sites and uncontrolled hazardous waste sites. Aerobic organisms may be able to degrade halogenated alphatics. Laboratory, pilot, and field studies have demonstrated that it is feasible to use microorganisms to reclaim contaminated soils and ground water.

The most developed and most feasible bioreclamation methods for treatment rely on aerobic microbial processes. This involves optimizing environmental conditions by providing an oxygen source and nutrients delivered to the subsurface through an injection well or infiltration system to enhance microbial activity. Given proper nutrients and sufficient oxygen, indigenous microorganisms generally degrade a wide range of compounds. Specially adapted or genetically manipulated microorganisms also are available and may be added to the treatment zone. Oxygen is generally supplied in the form of dilute hydrogen peroxide.

Anaerobic microorganisms also are capable of degrading certain organic contaminants. Methanogenic consortiums, groups of anaerobes that function under very reducing conditions, are able to degrade halogenated aliphatics while aerobic organisms cannot. The potential for anaerobic degradation has

been demonstrated in numerous laboratory studies and in industrial waste treatment processes that use anaerobic digesters or anaerobic waste lagoons as part of the treatment process.

Two basic bioreactor processes are available: (1) Aerobic fluidized bed (suspended sand and oxygen) to provide large scale areas to improve microbial degradation of soluble solids, and (2) Membrane aerobic reactor systems which prevent loss of cell mass and thereby provide high concentrations of cells to destroy pollutants. This process requires predeveloped microbes to be added to treatment systems.

The fluidized bed is a novel high-rate biological system that is quite different from the typical suspended growth systems. Generally, the wastewater is passed upward through a reaction vessel that is partially filled with fine-grained media. The wastewater velocity is sufficient to fluidize the bed. A biological mass grows on the media surface and effectively consumes the organics flowing through the system. Virtually 100 percent removal can be achieved during a 12-minute detention time.

4.2.1.6 Enzymatic Degradation

The bioengineered production of enzymes offers the potential for destroying toxic organics outside of a living cell. This eliminates the concerns associated with releasing new strains of living organisms into the environment.

4.2.1.7 Waste Stabilization Pond/Lagoon

Lagoons are used to remove dissolved and colloidal bio-degradable organics and suspended solids. Usually, a lagoon is a body of water contained in an earthen dike. Waste stabilization ponds can be aerated to enhance biological activity. Lagoons disadvantages include odor generation, freezing, large land requirements, and possible ground water contamination.

4.2.1.8 Activated Sludge

In the conventional activated sludge process, aqueous waste flows into an aeration basin where it is aerated for several hours. During this time, a suspended active microbial population maintained by recycling sludge

aerobically degrades organic matter in the stream. At the same time new cells are produced as a result of biological growth utilizing the contaminants as substrate. Pure oxygen has also been used in enclosed systems for enhancing oxygen transfer and reducing organic vapor emission.

The cells under aeration form a sludge that is settled out in a clarifier. A portion of the settled sludge is recycled to the aeration basin to maintain the microbial population, whereas, the remaining sludge undergoes volume reduction and disposal. Clarified water flows to disposal or further processing.

4.2.1.9 Powdered Activated Carbon Treatment (PACT)

Powdered activated carbon (PAC) is commonly used in wastewater facilities to adsorb soluble organic materials and to aid in the biodegredation process. A new technology has been developed that consists of addition of powdered carbon to the aeration basins of biological systems. This application is capable of handling higher waste flows, higher organic loading, and removal of refractory organics. PAC will add to sludge volume and total suspended solids in the effluent. Performance results have indicated a high success rate in treating industrial waste. The primary advantage of this process is that mixtures of biodegradable and nonbiodegradable compounds can be treated.

4.2.1.10 Sequencing Batch Reactor (SBR)

SBR is a biological activated sludge system operating in aerobic/anaerobic stages. SBR biotreatment consists of five sequential steps: fill, react, settle, draw, and idle. During fill, wastewater is fed to a tank containing acclimated activated sludge from the previous cycle. Aeration and mechanical mixing are provided to enhance the rate of aerobic biodegradation. After the react stage, the mixed liquor is biologically stabilized. Aeration and mixing are stopped, and clarification takes place during the Settle stage. During draw, the clear supernatant is withdrawn and discharged. During idle, anaerobic degradation can occur. Many variations of feed cycle, mixing strategies, and aeration are possible. SBR biotreatment is essentially a fill and draw activated sludge process. The advantages of more complete treatment, batch operation flexibility, feed

variation, and sludge separation make the SBR process an attractive technology for treating industrial wastes.

4.2.1.11 Trickling Filter/Fixed Film

Trickling filters are used in the biological decomposition of organic wastes. The process consists of a fixed bed of rock or synthetic media over which wastewater is applied for aerobic biological treatment. Microbial slimes form on the media which assimilate and oxidize hazardous constituents and contaminants in the wastewater. Modifications common to all types of trickling filtration include addition of various media, recirculation, multistaging, electrically powered distributors, forced ventilation, filter covers, and use of various methods of pretreatment and post-treatment of wastewater. However, some refractory toxics may pass through the system, and trickling filters are vulnerable to freezing. The surface are of the fixed bed is very important because this is where biological decomposition takes place.

4.2.1.12 Biological Towers

Biological towers are a modification of trickling filters. The medium such as polyvinyl chloride (PVC), polyethylene, polystyrene, or redwood is stacked into 16- to 20-ft towers. The contaminated water is sprayed across the top, and as it moves downward, air is pulled upward through the tower. A slime layer of microorganisms forms on the media and removes the organic contaminants as the water flows over the slime layer.

4.2.1.13 Rotating Biological Contractor (RBC)

The RBC is a fixed film treatment system for removal of carbonaceous and nitrogenous matter from wastewaters. The RBC consists of corrugated plastic disks mounted on a horizontal shaft that rotates slowly while approximately half the unit is immersed in wastewater. Biological growth develops on the rotating disk surfaces and consumes the soluble organic pollutants in the wastewater. Rotation of the media brings the biological growth in contact with the wastewater and exposes it directly to the air, thus promoting aerobic biological degradation of organics.

The fluidized bed combines features of activated sludge and trickling filters in one process. The fixed film with large surface area offers the stability and ease of operation of the trickling filters as well as the greater efficiency of the activated sludge system.

4.2.1.14 Publicly Owned Treatment Works (POTW)

Wastewater can be discharged to the local POTW for processing or treatment. Usually, a surcharge is required per gallon or pound of pollutants sent to the POTW. Regulations establish pretreatment requirements for POTWs. Hazardous wastes cannot be discharged directly to the POTW unless pretreatment requirements have been met. Small-quantity generators are exempt from pretreatment requirements.

4.2.2 ANAEROBIC TREATMENT

Anaerobic treatment generally is not as feasible for remediation as aerobic treatment. Anaerobic processes are slower, fewer compounds can be degraded, and the logistics of rendering a system anaerobic have not been developed to date. Given proper reducing conditions, degradation by methanogenic processes would be promising. Some research indicates that methanogenic consortiums are active in the subsurface and are capable of degrading certain organics. Most notably, methanogenic consortiums are able to degrade TCE, and other lower-molecular-weight halogenated organics that generally cannot be degraded by aerobic or other respiratory processes. Reductive dehalogenation appears to be the primary mechanism involved in degradation. Methanogenic consortiums also are able to degrade various aromatics, halogenated aromatics, and some pesticides.

4.3 THERMAL TREATMENT

Thermal destruction is a treatment method that uses high-temperature oxidation under controlled conditions to degrade a substance into products including carbon dioxide, water vapor, sulfur dioxide, nitrogen oxide, hydrogen chloride gas, and ash. Thermal destruction methods can be used to destroy organic contaminants in liquid, gaseous, and solid waste streams.

4.3.1 CRYOGENICS

Cryogenics involves the use of extremely cold temperatures to expose structural surface material. The cold temperatures decompose surface contaminants and facilitate surface removal. The cold surfaces are very brittle and are easily chipped and removed. However, this is a difficult application with potential for uneven surface removal. Skilled labor and large quantities of cryogenic fluid are required.

Another application of cryogenics is freeze crystalization. The basis of the freeze crystallization process is solid-liquid equilibria. Solvent and solutes can be crystallized by removing heat, lowering the temperature, and reaching the fusion temperature of the solvent or exceeding the solubility of the solute in the solvent. One added consideration is that crystals produced in this manner are very pure, excluding all other materials from the molecular matrix. This is especially true with water, so that the freeze process can remove equally, dissolved sacts, volatile organics, heavy metals, and toxic organic compounds.

4.3.2 EVAPORATION

Evaporation is a useful physical process that has been widely applied to waste management and handling, primarily as a waste treatment/volume reduction technique.

In any form of evaporation, the heat of vaporization must be supplied. Heat energy may be supplied by the sun and atmosphere, steam, electrical resistance heating, or other fuels to supply this energy-intensive process.

4.3.2.1 Solar

The evaporation lagoon is an open holding facility which depends solely on climatic conditions, such as solar energy evaporation, precipitation, temperature, humidity, and wind velocity, to effect dissipation of the waste. If the annual evaporation rate exceeds annual precipitation, solar evaporation lagoons may be considered as a method of disposal. Local health ordinances and state air pollution control regulations may limit the use of evaporation lagoons.

4.3.2.2 Enhanced

Due to fluctuations in evaporation and precipitation, enhanced evaporation may be required. Enhanced evaporation may require aerators, sprayers, or heat addition to overcome any net volume increase from precipitation. Enhanced evaporation may transfer a water pollution problem to an air pollution problem by generating malodorous and toxic vapors.

4.3.2.3 Spray Dryer (Flash Drying)

Spray drying is the instantaneous vaporization of organics and/or moisture from solids by introducing the waste stream into a hot gas stream. Spray drying is an effective disposal method but an expensive, energy-intensive process. Drying can also generate volatile organics that require scrubbing.

4.3.3 THERMAL DESORPTION/VOLATILIZATON

4.3.3.1 Indirect Heating

When organics are thermally desorbed from soils, one objective is to minimize the volume of off gases that must be treated. This can be accomplished by using an indirect source of heath to prevent dilution of the off gas by the products of combustion; however, the rate of transfer of heat from an indirect source limits the capacity of the process equipment. A process for relatively efficient indirect heat transfer was developed for use in the recovery of hydrocarbons from oil shale. This process uses large-scale equipment and will be investigated from treatment of soils contaminated with organics. This process may also be applied to water. Volatilization of organics may occur when an indirect source of heat is supplied.

4.3.3.2 Radio-Frequency Heating

This process is similar to microwave heating in terms of desorption but the power intensity per volume of soil is smaller. The radio frequency (i.e., 1-100 MHZ) can reach the depth of greater than 10 feet and is suitable for decontaminating hot spots. The desorbed vapor can be collected by suction and treated. This process may also be applied to water to volatilize organics.

4.3.3.3 Microwave Heating

Microwave heating treatment is a technique for desorbing organic molecules in a nonequilibrium flow discharge. Free electrons are formed with kinetic energy equivalent to several thousand degrees Celsius and they collide with other molecules at less than 100°C to form free radicals and ions. In this reactive system, organic molecules are rapidly decomposed into molecular fragments and polymeric materials. This process may also be applied to water to volatilize organics.

4.3.3.4 Steam Injection

One method of providing heat for thermal desorption of organics from soils is by injection of steam. In this case the steam not only provides heat to enhance volatilization but also can free the organics adsorbed to the soil particles and provide vapor flow to help carry the organics to the surface. This technique is especially attractive if there is a source of waste steam readily available. This process can also be applied to water to volatilize organic contamination.

4.3.3.5 Hot Gas

The hot gas concept employs the use of heated gases such as burner exhaust gases to thermally desorb contaminant residues. The circulation of hot gases in an enclosed building allows the building to act as an oven. Toxic gases are collected in an adsorber. The system is operated until the desired temperature is attained to ensure desorption. Building materials may be damaged, and decontamination time is lengthy. Hot gas applications may also be used as a direct treatment by taking contained material to a specially constructed structure for decontamination.

4.3.4 SURFACE FLASHING/FLAMING

This technology involves the use of controlled high-temperature flames applied to noncombustible surfaces to thermally degrade contaminants. Contaminated materials may be burned in-situ or placed in a pile with auxiliary fuel and ignited.

Flaming provides degradation or rapid destruction of organic residues contacted. No elaborate equipment is required and little labor is involved.

The method is particularly useful for decontaminating soils or sewers, which are highly contaminated with volatile organics, prior to landfilling or other disposal methods. Flaming is a hand-held operation where as flashing is usually remotely controlled.

Surface flashing is primarily a surface decontamination technique. This method of disposal produces gaseous emissions, particulate matter, and some nonvolatilized residue. Gaseous and particulate emissions can be reduced by controlling the quantity and nature of the material burned.

Surface flashing/flaming has been used widely for decontamination purposes and for munitions destruction at military installations. The technology may be applied to unexploded ordnance (UXO), residue scattered around burning grounds, and as a decontamination procedure for sewer lines.

4.3.5 OPEN BURNING

Open burning is the combustion of any material and has the following characteristics:

- No control of combustion air to maintain adequate temperature for efficient combustion;
- No containment of the combustion-reaction in an enclosed device to provide sufficient residence time and mixing for complete combustion; and
- No control of emission of the gaseous combustion products.

Open burning of explosives is an acceptable practice when performed in accordance with RCRA requirements [40 Code of Federal Regulations (CFR) 265.382].

4.3.6 CO_2 LASER

This decontamination method utilizes a CO_2 (carbon dioxide) laser to direct an infrared laser light beam onto a contaminated building surface. Surface contamination is thermally decomposed by heat conduction from the irradiated surface. This application is limited to line-of-sight locations, and a highly complex beam guidance system would be necessary.

4.3.7 THERMAL OXIDATION/INCINERATION

4.3.7.1 Rotary Hearth

The rotary hearth or cyclone furnace is a refractory-lined steel cylinder with a single rotating hearth. Wastes are introduced at the outer edge of the hearth and are gradually moved inward by a fixed plow toward an ash discharge chute at the center. Combustion air is injected above the hearth at high tangential velocity in the opposite direction to hearth rotation. The hearth is operated at high temperatures with exit gases leaving the system at approximately 820°C. Combustion products must pass through this high-temperature central vortex before leaving the furnace, and this passage essentially completes combustion of all organics without the need for an afterburner.

Cyclone furnaces have been used to incinerate sewage sludge, oil, chemical sludges, aqueous organic suspensions, solvents, and chlorinated hydrocarbons. The advantages of cyclone incineration stem from the fact that combustion air passes over rather than through the waste material. The furnace temperature is less susceptible to upsets caused by uneven bed conditions, and there is less particulate entrainment.

4.3.7.2 Multiple-Hearth

A multiple hearth incinerator consists of a refractory-lined steel shell, a rotating central shaft, a series of solid flat hearths, a series of rabble arms with teeth for each hearth, an air blower, waste feeding and ash removal systems, and fuel burners mounted on the walls. It can also be equipped with an afterburner, liquid waste burners, and side ports for injection. Temperature in the burning zone ranges from 760 to 980°C and residence time may be very long.

The multiple hearth incinerator can be used for the disposal of all forms of combustible industrial waste materials, including sludges, tars, solids, liquid, and gases. The incinerator is best suited for hazardous sludge destruction. The multiple hearth incinerator can treat the same wastes as the rotary kiln provided pretreatment of solid waste is applied. The principal advantages of multiple hearth incinerator includes high residence time for sludge and low volatile materials, the ability to handle a variety

of sludges, the ability to evaporate large amounts of water, high fuel efficiency, and the utilization of a variety of fuels. The greatest disadvantages of the technology include susceptibility to thermal shock and inability to handle wastes requiring very high temperatures. In addition, control of supplemental fuels firing is difficult. Ash from wastes will fuse if the hearth is operated at a temperature above the ash slagging temperature.

4.3.7.3 Fluidized Bed/Circulating Bed

The fluidized bed incinerator consists of a cylindrical, vertical, refractory-lined vessel containing a bed of inert granular material, usually sand, on a perforated metal plate. Combustion air is introduced through a plenum at the bottom of the incinerator and rises vertically, fluidizing the bed and maintaining turbulent mixing of bed particles. Waste material is injected into the bed, where combustion occurs as heat is transferred from the bed into the injected wastes. Auxiliary fuel is usually injected into the bed. Bed temperatures vary from 760 to 870^{o}C. Since the mass of the heated, turbulent bed is much greater than the mass of the waste, heat is rapidly transferred to the waste materials. A residence time of a few seconds for gases and a few minutes for liquids is sufficient for combustion.

Fluidized bed incinerators are a relatively new design and currently are used for liquid, solid, and gaseous combustible wastes. The most typical wastes treated in fluidized beds are slurries and sludges. Some wastes require pretreatment such as drying, shredding, and sorting.

Circulating bed combustion (CBC) is an outgrowth of conventional fluidized-bed incineration. However, the circulating fluid bed operates with higher velocities than conventional fluid beds, and the fluidized material is recirculated within the system and returned to the feed section.

CBC is suitable for burning solid, liquid, sludge, or gaseous waste. The advantages of this incinerator are similar to those of a conventional

fluidized bed system with lower susceptibility to corrosion of the boiler, a less complicated scrubbing system, close temperature control, and dry solid waste recovery.

4.3.7.4 Rotary Kiln

Rotary kilns are capable of handling a variety of solid and liquid wastes. Rotary kiln incinerators are horizontal, cylindrical, refractory-lined shells and are fueled by natural gas, oil, or pulverized coal. Most of the heating of the waste is due to heat transfer with the combustion product gases and the walls of the kiln. The unit consists of the kiln and an afterburner.

Residence time and temperature depend on waste combustion characteristics. Residence times can range from a few seconds to an hour or more for bulk solids. Combustion temperatures range from 820 to 1,600^{o}C.

Rotary kilns are capable of burning waste in any physical form. They can incinerate solids and liquids independently or in combination and can accept waste feed without any preparation. Hazardous wastes that have been treated in rotary kilns include PCBs, tars, obsolete munitions, and bottoms from solvent reclamation operations. Because of their ability to handle waste in any physical form and their high incineration efficiency, rotary kilns are the preferred method for treating mixed hazardous solid residues.

The limitations of rotary kilns include susceptibility to thermal shock; necessity for careful maintenance; need for additional air due to leakage; high particulate loadings; and relatively low thermal efficiency.

4.3.7.5 Industrial Kiln

Industrial kilns are used throughout the country to produce cement, lime, aggregates, asphalt, and clay. They can potentially be used to destroy wastes, and can sometimes use hazardous wastes as a supplemental energy source.

Only rotary kilns constructed of steel casings lined with refractory brick are acceptable for receiving hazardous waste. Blended fuels are fed into

the upper end of the kiln, and waste is fired at the lower end. Kiln temperatures are about 1,600°C for lime kilns and less than 1,100°C for aggregate and clay drying kilns.

4.3.7.6 Infrared Electric Furnace

A relatively new type of incinerator, the electric furnace, was introduced in 1975. The electric or infrared furnace consists of a horizontal metal mesh conveyor belt which passes under a series of electrical heating elements. The shell is steel lined with ceramic fiber insulation. Feed and combustion air enter the furnace at opposite ends. Auxiliary fuel in the form of gas or oil is often used. Ceramic fiber insulation can be heated and cooled rapidly without adverse effects, making the furnace ideally suited to intermittent operation.

Advantages of this type furnace include a quiescent combustion zone for low particulate emissions; reduced gaseous emissions since no or limited fossil fuel is used; up to 50 percent turndown and a high degree of control; and long residence times.

4.3.7.7 Pyrolysis/Electric Heater

Pyrolysis is the thermal conversion of organic material into solid, liquid, and gaseous components. Pyrolysis takes place in an oxygen-deficient atmosphere at temperatures from 480 to 870°C. The volatile organics generated in the process are burned in a second-stage fume incinerator at temperatures of 980 to 1,600°C. The two-stage process minimizes the volatilization of inorganic components and ensures that inorganics, including heavy metals, form an insoluble solid char residue. The technology may be used for the destruction of materials containing carbon, hydrogen, and oxygen. Pyrolysis cannot handle wastes containing nitrogen, sulfur, or sodium.

An electric reactor uses an electrically heated fluid wall reactor to pyrolyze waste contaminants from particles such as soils. Emissions and residuals include mostly nitrogen, water and chloride, and/or hydrogen chloride trapped in the scrubber ash components in the residue.

4.3.7.8 Submerged Quench Liquid Incineration

This process is applicable to liquids that contain large concentrations of inorganic salts in addition to organic contaminants. The solutions are metered into a burner and combustion chamber where the water is vaporized and the organics are combusted at 982 to 1,093°C. The resultant off gases are down drafted in the chamber and quenched and scrubbed with water. The inorganic salts form a concentrated solution in the water and the off gases are further scrubbed and discharged to the atmosphere. The concentrated salt solution can either be disposed of, or can be further treated to produce a dry salt cake.

4.3.7.9 Transportable Thermal Treatment Unit (TTTU)

Mobile incineration or transportable thermal treatment units (TTTU) have not been widely used, but demand for this technique is increasing as a result of future bans on landfill disposal of certain wastes. Existing mobile systems include liquid injection and rotary kiln incinerators equipped with secondary combustion chambers and air pollution controls. These mobile incinerators are capable of handling a variety of wastes including PCBs, volatile organics, and soils. The preliminary advantage of the mobile incinerator is onsite treatment, which eliminates the need for offsite transport.

4.3.7.10 Low-Temperature Thermal Decomposition

Low-temperature thermal decomposition is the chemical degradation of organic molecules at less than incineration temperatures. Kinetic studies of the low-temperature thermal decomposition of explosives and volatile organic solvents such as trichloroethylene (TCLE), trichloroethane (TCE), and xylene by the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) resulted in kinetic expressions and destruction efficiencies demonstrating significant decomposition.

4.3.7.11 Wet Air Oxidation

Wet air oxidation is the aqueous phase oxidation of dissolved or suspended organic substances at elevated temperature and pressures. Water, which make up the bulk of the aqueous phase, serves to catalyze the oxidation reactions so they can proceed at lower temperatures, and at the same it serves to

moderate the oxidation rates by removing excess heat by evaporation. Water also provides an excellent heat transfer medium which enables the wet air oxidation process to be thermally self-sustaining with relatively low organic feed concentrations. Wet air oxidation can be used to oxidize any material, including inorganics with a COD value. A significant advantage to the process is the minimal air pollution problems that it causes; contaminants tend to stay in the aqueous phase. Furthermore, materials such as sulfur compounds, chlorinated hydrocarbons, or heavy metals end up in their highest oxidation state, i.e., sulfates, hydrochloric acid, or a salt thereof.

4.3.7.12 High-Temperature Fluid Wall (HTFW)

HTFW quickly reduces organic wastes to their elemental state in a high-temperature process at approximately 2,200°C. The process is completed in a patented reactor which consists of a tubular core of refractory material capable of emitting radiant energy supplied by large electrodes in the jacket of the vessel. During the process, an inert gas is injected to coat the wall of the reactor and prevent destruction from high temperatures. HTFW has been used to treat PCB-contaminated earth and other wastes. It ensures high destruction efficiency and eliminates the formation of intermediate pyrolysis products, but requires some preparation of feed material and incurs high energy. Another type of HTFW is an advanced electric reactor.

4.3.7.13 Molten Salt/Sodium Fluxing

The molten salt incinerator can be used for destruction of hazardous liquids and solids. In this method, wastes are catalyzed when they contact hot molten salt maintained at a temperature between 700 and 1,000°C. Hot gases rise through the molten salt bath, and pass through a secondary reaction zone and off-gas cleanup system before discharging to the atmosphere. Supplemental fuel may be required when wastes are not sufficiently combustible to maintain temperatures.

Liquid, free-flowing powders, sludges, and shredded solid wastes can be fed directly into the incinerator. The technology has been demonstrated to be highly effective for chlorinated hydrocarbons, including PCBs, solvents, and

malathion. However, the process appears to be sensitive to materials containing high ash content or high chlorine content.

4.3.7.14 Molten Glass

A molten glass electromelt reactor uses a pool of molten glass as the heat transfer mechanism to destroy organics and to capture ash and inorganics. The emissions include acid gas and particulates. All residue is contained in the glass. The advantages include significant volume reduction, treatability of most wastes, and the stabilized glass residual. The process is based on existing glass making technology.

4.3.7.15 Hot Plasma

This decontamination method is based on the use of hot plasma at 2,200 to 20,000°C to thermally or chemically decompose contaminants. Thermal decomposition is obtained by heat transfer from the hot plasma. Chemical decomposition can be caused by reaction of ionized gases and electrons in the plasma with contaminants. The mode of application could take the form of a plasma torch resembling conventional flaming techniques. This process causes extensive damage to structures and has high energy costs.

4.3.7.16 Supercritical Water Oxidation

The process is suitable for concentrated aqueous wastes. The organics would be mineralized under supercritical conditions (450-600°C, 3,500-5,000 psig). Inorganic salts have low water solubility under such conditions and can be separated as solids. The process was developed for above-ground treatment. A deep shaft underground process is also available. Destruction of highly toxic wastes has reached efficiencies of 99.99 percent to 99.999 percent.

4.3.7.17 Catalytic

Catalytic oxidation is a relatively low temperature incineration technique. Insertion of a catalytic agent in the gas stream induces destruction of the contaminant at lower temperatures than direct-flame fume incineration. The catalyst normally used is a noble metal compound such as platinum or rhodium. The catalytic agent is used in small quantities and is deposited on a support material such as alumina. The noble metal is not used by

itself. This technique is not applicable to all odor compounds, nor to gases with relatively highly particulate loadings. Where it can be used, however, it is very effective in odor destruction and is more economical than fume incineration.

5.0 IN-SITU TREATMENT

In-situ treatment entails the use of chemical agents, biological agents, or physical manipulations which degrade, remove, or immobilize contaminants; methods for delivering solutions to the subsurface; and methods for controlling the spread of contaminants and treatment reagents beyond the treatment zone. In-situ biodegradation, commonly referred to as bioreclamation, is based on the concept of stimulating microorganisms to decompose the contaminants of concern. In-situ chemical treatment involves the injection of a specific chemical or chemicals into the subsurface to degrade, immobilize, or flush the contaminants. Physical methods involve manipulation of the soil using heating, freezing, or other means. In many instances, a combination of in-situ and above ground treatment will offer the best method of treatment at an uncontrolled waste site.

In-situ treatment technologies are generally not as developed as other currently available remedial technologies for restoring contaminated aquifers. However, some in-situ treatment technologies have demonstrated success in actual site remediations. In addition, most of the methods are based on standard waste treatment technologies and are conceptually applicable as in-situ treatment methods. Applicability of in-situ methods must generally be determined on a site-specific basis using laboratory- and pilot-scale testing.

5.1. PHYSICAL/CHEMICAL TREATMENT

5.1.1 SOLIDIFICATION AND STABILIZATION

Solidification/stabilization are terms used to describe treatment systems that accomplish one or more of the following objectives:

- Improve waste handling or other physical characteristics of the waste;
- Decrease the surface area across which transfer or loss of contained pollutants can occur; and/or
- Limit the solubility or toxicity of hazardous constituents.

Solidification is used to describe processes where these results are obtained primarily, but not exclusively, by production of a monolithic block

of waste with high structural integrity. The contaminants do not necessarily interact chemically with the solidification reagents, but are mechanically locked within the solidified matrix. Contaminant loss is minimized by reducing the surface area.

Stabilization methods usually involve the addition of materials that limit the solubility or mobility of waste constituents even though the physical handling characteristics of the waste may not be improved. Methods involving combinations of solidification and stabilization techniques are often used. In some instances, the solidifying/stabilizing agents can be added directly to hazardous materials in place.

5.1.1.1 Sorption

Sorbents include a variety of natural and synthetic solid materials used to eliminate free liquid and improve waste handling characteristics. Commonly used natural sorbent materials include fly ash, kiln dust, vermiculite, and bentonite. Synthetic sorbent materials include activated carbon which sorbs dissolved organics, Hazorb which sorbs water and organics, and Locksorb which is reportedly effective for all emulsions.

Some sorbents have been used to limit the escape of volatile organic compounds. Sorbents can be useful in waste containment when used to modify the chemical environment and maintain the pH and redox potential to limit solubility. Although sorbents prevent drainage of free water, they do not necessarily prevent leaching of waste constituents, and secondary containment is generally required.

The quantity of sorbent material necessary for removing free liquid varies widely depending on the nature of the liquid phase, the solids content of the waste, the moisture level in the sorbent, and the occurrence of any chemical reactions that absorb liquids. It is generally necessary to determine the quantity of sorbent needed on a case-by-case basis.

5.1.1.2 Lime-Fly Ash Pozzolan Process

Pozzolanic materials are those that set to a solid mass when mixed with hydrated lime. Natural pozzolanic materials called pozzolana consist of

either volcanic lava masses called tuff or deposits of hydrated silicic acid of mostly organic origin, such as diatomaceous earth. Artificial pozzolana are materials such as blast-furnace slag, ground brick, and some fly ashes from powdered coal furnaces.

Solidification and stabilization of waste using lime and pozzolanic material requires mixing with a carefully selected, reactive fly ash or other pozzolanic material, to a pasty consistency. Hydrated lime, calcium hydroxide, is blended into the waste-fly ash mixture. Typically, 20 to 30 percent lime is needed to produce a strong pozzolan. The resulting moist material is packed or compressed into a mold to cure or is placed in the landfill and rolled.

Standard testing systems and standard specifications exist for pozzolanic materials, especially for fly ash. The specifications take into account the chemical composition (percentage SiO_2, SO_3, and moisture), and physical properties, (fineness, pozzolanic activity with lime, and specific gravity).

5.1.1.3 Pozzolan-Portland Cement Process

A wide variety of treatment processes incorporate Portland cement as a binding agent. Pozzolanic products are those materials with fine-grained, noncrystalline and reactive silica which are frequently added to Portland cement to react with any free calcium hydroxide and thus improve the strength and chemical resistance of the concrete-like product. In waste solidification, the pozzolanic materials such as fly ash are often used as sorbents. Much of the pozzolan in waste processing may be inactivated by the waste. Any reaction that does occur between the Portland cement and free silica from the pozzolan adds to the product strength and durability. The types of Portland cement used for solidification can be selected so as to emphasize a particular cementing reaction.

Cement/fly ash processes typically are used in conjunction with sorbents or other additives which decrease the loss of specific hazardous materials from the rather porous, solid products. Such adaptations of the technology are also often necessary because some materials inhibit the binding action in Portland cement.

5.1.1.4 Thermoplastic Microencapsulation

Thermoplastic microencapsulation has been successfully used in nuclear waste disposal and can be adapted to special industrial wastes. This technique for isolating waste involves drying and dispersing it through a heated, plastic matrix. The mixture is then permitted to cool to form a rigid but deformable solid. The most common material used for waste incorporation is asphalt, although other materials such as polyethylene, polypropylene, wax, or elemental sulfur can be employed for specific wastes.

5.1.1.5 Macroencapsulation

Macroencapsulation systems contain potential pollutants by bonding an inert coating or jacket around a mass of cemented waste. This type of waste stabilization is often effective when others are not because the waste block jacket or coating completely isolates the waste from its surroundings. The waste may be stabilized, microencapsulated, and/or solidified before macroencapsulation so that the external jacket becomes a barrier designed to overcome the shortcomings of available treatment systems.

5.1.1.6 Vitrification

In-situ vitrification is a mobile, thermal process for converting contaminated soil into a chemically inert, stable glass and crystalline waste form resembling natural obsidian. A selected waste area is subjected to electric meter technology, with electrodes utilizing the Joule heating principle with temperatures above 1,700 ^{o}C.

The vitrified zone incorporates nonvolatile hazardous elements, such as heavy metals, and destroys organic components by pyrolysis. The innovative process was initially developed for stabilization of transuranic-contaminated wastes. The process is an effective option for isolating hazardous waste and providing long-term durability of the waste.

5.1.1.7 Polymerization

In-situ polymerization involves injection of a catalyst into a contaminated media to cause transformation of an organic monomer, such as, styrene, vinyl chloride, isoprene, methyl methacrylate, and acrylonitrile. The

polymerization reaction transforms the once fluid substance into a gel-like, nonmobile mass.

5.1.2 VACUUM EXTRACTION

One alternative to pumping and treating ground water or excavation of soil is to remove volatile organics soil gas extraction. This system utilizes similar principles as the active interior gas collection and recovery system. Inclined perforated pipes, piezometers, or gas wells are installed and connected by a common header to an air vacuum pump. The extracted vapors can be discharged, flared, or treated by activated carbon.

5.1.3 FLUSHING

Soil flushing is a treatment process which can be employed in-situ by passing extractant solutions through in-place soil to extract inorganic or organic compounds. The solutions are extracted by recovery wells and treated. Extractant solutions used include water, surfactants, acids or bases, chelating agents, and oxidizing and reducing agents.

5.1.4 VENTING

Another alternative to pumping and treating ground water or excavation of soil is to remove volatile organics by venting. This system utilizes similar principles as the active interior gas collection and recovery system. Inclined perforated pipes, piezometers, or gas wells are installed and vented. The vented vapors can be discharged, flared, or treated by activated carbon.

5.1.5 ADSORPTION

5.1.5.1 Permeable Treatment Beds

Permeable treatment beds are essentially excavated trenches placed perpendicular to ground water flow and filled with an appropriate treatment material. Some materials used in treatment beds are limestone, crushed shell, activated carbon, gluaconitic green sands, and synthetic ion exchange resins. The system is applicable to relatively shallow ground water tables containing a plume. To date, there has been no application of permeable treatment beds at hazardous waste sites. However, bench- and pilot-scale testing has provided preliminary quantification of treatment bed

effectiveness. Potential problems exist in using a permeable treatment bed. These include saturation of bed material, plugging of bed with precipitates, and short life of treatment materials. Permeable treatment beds are only recommended for short term cleanup.

5.1.6 NEUTRALIZATION

Neutralization involves injecting dilute acids or bases into the ground water to adjust the pH. Neutralization can serve as pretreatment prior to in situ biodegradation, oxidation, or reduction to optimize the pH range; to neutralize acidic or basic plumes that need no other treatment; or to neutralize ground water following another treatment. Neutralization also can be used during oxidation, reduction, or precipitation to prevent the formation of toxic gases, such as, hydrogen sulfide and hydrogen cyanide.

5.1.7 PRECIPITATION/FLOCCULATION

Precipitation is a physiochemical process whereby some or all of a substance in solution is transformed into a solid phase. It is based on alteration of the chemical equilibrium relationships affecting the solubility of inorganic species. Removal of metals as hydroxides or sulfides is the most common precipitation application in wastewater treatment.

Flocculation describes the process by which small unsettleable particles suspended in a liquid medium agglomerate into larger, settleable particles. The mechanisms by which flocculation occurs involve surface chemistry and particle charge phenomena. Typically, chemicals used to cause flocculation include alum; lime; various iron salts, such as, ferric chloride and ferrous sulfate; and organic flocculating agents, referred to as poly-electrolytes.

5.1.8 CHELATION

The use of celating agents may be an effective means of immobilizing metals, although considerable research is needed in this area. Depending on the specific chelating agent, stable metal chelates may be highly mobile or may be strongly sorbed to the soil. Tetran is an example of a chelating agent that is strongly sorbed to clay in soils.

5.1.9 HYDROLYSIS

Hydrolysis involves the displacement of a group on an organic molecule with a hydroxyl group from water, and can be used in-situ to promote the same process which can be conducted as a direct treatment process. The parameters that affect the rate of hydrolysis are temperature, solvent composition, catalysis, and pH. Adjustment of pH has the greatest potential to enhance in-situ hydrolysis. The rate of hydrolysis can be increased up to an order of magnitude for a change of one standard unit in pH. Several classes of compounds have a good potential for in-situ degradation by hydrolysis. Because a hydrolysis product may be more toxic than its precursor compound, the pathways for reactions must be determined to ensure toxic products are not produced. However, a collection system should be incorporated as a fail-safe measure to prevent migration of the treatment reagents and any contaminants that are not successfully treated.

5.1.10 OXIDATION/REDUCTION

Redox reactions alter the oxidation state of a compound through loss or gain of electrons and can be used to detoxify, precipitate, or solubilize metals and decompose, detoxify, or solubilize organics. Oxidation may render organics more amenable to biological degradation. As with many of these chemical treatment technologies, oxidation/ reduction techniques are standard wastewater treatment approaches, but application to in-situ treatment is largely conceptual.

Of the numerous oxidizing agents available, three have been considered potentially useful in the in-situ detoxification of ground water and soils contaminated with organics: hydrogen peroxide, ozone, and hypochlorites. Selection of the appropriate oxidizing agent depends on the substance or substances to be detoxified, as well as the feasibility of delivery and environmental safety. Although there are some compounds that will not react with hydrogen peroxide but will react with ozone or hypochlorite, hydrogen peroxide appears to be the most feasible agent for in-situ treatment.

Chemical reduction does not appear as promising as oxidation for the treatment of organics. Although researchers have demonstrated reductive dehalogenation of a variety of chlorinated organics and reduction of

unsaturated aromatics and aliphatics in laboratory studies using catalyzed metal powders, the treatment reagents are costly and the effectiveness of chemical reduction in soils has not been demonstrated.

A number of disadvantages associated with the use of oxidizing and reducing agents limit their use at hazardous waste sites. The treatment compounds are nonspecific, which may result in degradation of nontargeted compounds. The formation of more toxic or more mobile degradation products is possible, particularly with oxidation. Also, the introduction of these chemicals into the ground water system may create a pollution problem. As with soil flushing, uncertainty exists with respect to obtaining adequate contact with the contaminants in the plume.

5.1.11 VACUUM DUSTING

In-situ vacuum dusting is the removal of dust and debris from a contaminated surface by air suction. It can be applied in the decontamination of structures where contaminants may be concentrated in surface dust. Vacuum dusting is most effective when used in conjunction with other treatment processes which chemically or physically loosen surface particulates.

5.1.12 HYDRAULIC SCOUR

Hydraulic scour uses water jets at high pressures, (500 to 20,000 psi), to impact surfaces for removal of contaminants. Surface debris and water are then collected and decontaminated. Surfactants, abrasives, and heat may complement the process. This offers a relatively inexpensive, nonhazardous surface decontamination technique using off-the-shelf equipment. Many manufacturers produce a wide range of hydroblasting systems and high-pressure pumps. Hydraulic scour may not effectively remove contaminants that have penetrated the structural material beyond the surface. Large amounts of water must be collected and treated.

5.1.13 MECHANICAL SCOUR

Sandblasting or gritblasting is a mechanical scour surface removal technique in which an abrasive such as sand or steel pellets is used to uniformly remove building material layers containing contaminants. Sandblasting is a widely used surface removal technique and can simultaneously remove paint

and contaminants near the surface. Large amounts of contaminated dust and debris are generated by this process.

5.1.14 ACID ETCH

This decontamination process applies acid or bleach to a surface to promote corrosion. Neutralization and removal of the surface layer follows. The debris are collected and decontaminated. The acid itself may cause decomposition of the contaminant. This application is a hazardous operation requiring large quantities of acidic hazardous materials and skilled labor.

5.1.15 DRILL AND SPALL

The drill and spall technique is capable of removing approximately 6 inches of surface layer from concrete or similar materials. The technique consists of drilling holes 1 to 1.5 inches in diameter approximately three inches deep into the surface. The spalling tool bit is inserted into the hole and hydraulically spreads to spall the contaminated concrete. This application is effective on large-scale jobs, but is effective only as a surface treatment of concrete. Substantial amounts of contaminated debris require processing.

5.1.16 SCARIFICATION

Scarifier techniques remove approximately 1 inch of surface layer from concrete or similar materials. The scarifier tool consists of pneumatically operated piston heads that strike a surface, causing concrete to chip off a structure. The piston head consists of multipoint tungsten carbide bits. This method of decontamination can achieve a deeper removal of surface contaminants and has greater applicability compared with most surface removal techniques. Substantial amounts of contaminated debris are generated, requiring further processing.

5.1.17 STEAM CLEANING

Steam cleaning physically extracts contaminants from building materials and equipment surfaces. The steam is applied by hand-held wands or automated systems, and the condensate is collected for treatment. Steam cleaning is a relatively simple technique. Depending on the contaminant, thermal

decomposition and/or hydrolysis may occur. This technique is only effective for surface decontamination.

5.1.18 SEALANT/ENCLOSURE

In this technique, contaminants or contaminated structures are physically separated from building occupants or the ambient environment by a barrier. An encapsulating or enclosing physical barrier can consist of a variety of sealants, resins, or concrete. Acting as an impenetrable shield, this barrier keeps contaminants inside and away from clean areas.

5.2 BIOLOGICAL TREATMENT

5.2.1 AEROBIC

The first in-situ remediation of hydrocarbon contamination was conducted using a treatment approach involving stimulating the indigenous microorganisms through the delivery of nutrients and air to the subsurface. Considerable developments have been made subsequently, and many treatment approaches have been used successfully to enhance biodegradation in contaminated zones. Specialized microorganisms, either adapted strains or genetically altered strains, have been used, and hydrogen peroxide or ozone appear to be feasible alternatives to air or pure oxygen as an oxygen source. Biological degradation is currently being tested at hazardous waste disposal sites containing a complex range of organics.

5.2.1.1 Land Farming

Land farming involves tilling of the soil in-place to enhance microbial degradation of contaminants in soil. Through volatilization and biodegradation, organic contaminant levels are decreased in the near surface soils.

5.2.1.2 Bio-Uptake

An additional type of in-situ bio-uptake involves agricultural crops which are planted in zones with near surface contamination. Pesticide levels have been known to decrease in soils after continued agricultural use.

5.2.1.3 Biodegradation

In-situ biodegradation is a technique for treating zones of contamination by

microbial degradation. The basic concept involves altering environmental conditions to enhance microbial catabolism or co-metabolism of organic contaminants, resulting in the breakdown and detoxification of those contaminants. The technology has been developed rapidly over recent years, and bioreclamation appears to be one of the most promising in-situ treatment techniques.

Considerable research conducted over the past several decades has confirmed that microorganisms are capable of breaking down many organic compounds considered to be environmental and health hazards at spill sites and uncontrolled hazardous waste sites. Laboratory, pilot, and field studies have demonstrated that it is feasible to use microorganisms in-situ to reclaim contaminated soils and ground water.

The most developed and most feasible bioreclamation methods for in-situ treatment rely on aerobic microbial processes. This involves optimizing environmental conditions by providing an oxygen source and nutrients delivered to the subsurface through an injection well or infiltration system to enhance microbial activity. Given proper nutrients and sufficient oxygen, indigenous microorganisms generally degrade a wide range of compounds. Specially adapted or genetically manipulated microorganisms also are available and may be added to the treatment zone.

5.2.1.4 Enzymatic Degradation

Enzymatic approaches to the degradation of toxic materials offer many attractive features. They can be used onsite and require no expensive hardware or engineering. They are usually non-toxic and non-corrosive so that extensive cleanup is unnecessary. Enrichment cultures have been used for many years to select microorganisms with unique metabolic properties. The growth medium is selected so that only the desired organism grows. After the bacteria have been selected, it is then possible to study their enzymatic reactions to determine whether they are useful. Promising enzymes can be purified and further characterized. The purified enzymes are then formulated into a usable package by attaching them onto a solid support, stabilizing them by one of several methods, or modifying them to change their properties. Large scale production usually requires cloning of the

gene that codes for the desired protein production in an expression system. In the natural state, enzymes for secondary metabolites are usually in such low concentration that commercial utilization is not feasible; however, approximately 20 percent of the cellular protein may be produced when the respective gene is spliced into a high copy plasmid and introduced into an optimally functioning system. Most of the research on enzymatic methods for detoxification is in the basic research or early development stage so that commercial application will not be possible for several years. While one enzyme will never eliminate all contamination, a series of enzymes should permit detoxification of most hazardous materials under conditions which do not pose additional hazards or require extensive clean-up or disposal following the degradation.

5.2.2 ANAEROBIC

Anaerobic treatment generally is not as feasible for site remediations as aerobic treatment. Anaerobic processes are slower, fewer compounds can be degraded, and the logistics of rendering a site anaerobic have not been developed to date. Given proper reducing conditions, degradation by methanogenic processes would be promising. Some research indicates that methanogenic consortiums are active in the subsurface and are capable of degrading certain organics. Most notably, methanogenic consortiums are able to degrade TCE, and other lower-molecular-weight halogenated organics that generally cannot be degraded by aerobic or other respiratory processes. Reductive dehalogenation appears to be the primary mechanism involved in degradation. Methanogenic consortiums also are able to degrade various aromatics, halogenated aromatics, and some pesticides.

5.3 THERMAL TREATMENT

5.3.1 CRYOGENICS

Crygenics involves the use of extremely cold temperatures to expose structural surface material. The cold temperatures decompose surface contaminants and facilitate surface removal. The cold surfaces are very brittle and are easily chipped and removed. However, this is a difficult application with potential for uneven surface removal. Skilled labor and large quantities of cryogenic fluid are required.

5.3.2 EVAPORATION

Solar and enhanced in-situ evaporation is a useful physical process that has been widely applied to waste management, primarily as a waste treatment/volume reduction technqiue.

In any form of evaporation, the heat of vaporization must be supplied. Heat energy may be supplied by the sun and atmosphere, steam, electrical resistance heating, or other fuels to supply this energy-intensive process.

5.3.3 THERMAL DESORPTION/VOLATILIZATION

5.3.3.1 Indirect Heating

When organics are thermally desorbed from soils, one objective is to minimize the volume of off gases that must be treated. This can be accomplished by using an indirect source of heat to prevent dilution of the off gads by the products of combustion; however, the rate of transfer of heat from an indirect source limits the capacity of the process equipment. A process for relatively efficient indirect heat transfer was developed for use in the recovery of hydrocarbons from oil shale. This process uses large-scale equipment and will be investigated for treatment of soils contaminated with organics. This process may also be applied in water to volatilize organic contamination.

5.3.3.2 Radio-Frequency Heating

In-situ this process is similar to microwave heating in terms of desorption but the power intensity per volume of soil is smaller. THe radio frequency (i.e., 1-100 MHZ) can reach a depth of greater than 10 feet and is suitable for decontaminating hot spots. The desorbed vapor can be collected by suction and treated. This process may also be applied to water and volatilize organic contamination.

5.3.3.3 Microwave Heating

In-situ microwave plasma treatment is a technique for desorbing organic molecules in a nonequilibrium flow discharge. Free electrons are formed with kinetic energy equivalent to several thousand degrees Celsius and collide with gas at less than 100°C to form free radicals and ions. In this reactive system, organic molecules are rapidly decomposed into molecular

fragments and polymeric materials. This process may also be applied to water to volatilize organic contamination.

5.3.3.4 Steam Injection

One method of providing heat for in-situ thermal desorption of organics from soils is by injection of steam. In this case, the steam not only provides heat to enhance volatilization but also can free the organics adsorbed to the soil particles to provide vapor flow to help carry the organics to the surface. This technique is especially attractive if there is a source of waste steam readily available. This process can also be applied to water to volatilize organic contamination.

5.3.3.5 Hot Gas

The hot gas concept employs the use of heated gases such as burner exhaust gases to thermally desorb contaminant residues. The circulation of hot water in an enclosed building allows the building to act as an oven. Toxic gas are collected in an adsorber. The system is operated until the desired temperature is attained to ensure agent destruction. Building materials may be damaged, and decontamination time is lengthy.

5.3.4 THERMAL OXIDATION/INCINERATION

5.3.4.1 Infrared Radiant Heating

Radiant heating involves the use of fuel or electrically powered radiant heaters to heat building materials to the decomposition temperature of the contaminant. Off-the-shelf commercial radiant heaters may be used. Heating external and internal surfaces simultaneously may prevent volatilization of agent to uncontaminated areas and provide more rapid heat-up rates. However, heating complex surface areas in a building would be difficult because of configurations of radiant heaters.

5.3.4.2 Electrical Resistant Contact Heating

Contact heating is a thermal decomposition process for structures which generate high temperatures through electrical resistance coils. The generated heat is applied to the building material. Thermal decomposition of contaminants can be achieved by adjusting temperatures.

5.3.4.3 Hot Plasma

This technology uses a plasma arc device to create extremely high temperatures approaching 10,000 ^{o}C for waste destruction in highly toxic liquids. Gaseous emissions (mostly H_2, CO), acid gases in the scrubber, and ash components in scrubber water are the residuals. The system's advantages are that it can destroy refractory compounds, the equipment can be made portable and typically the process has a very short on/off cycle.

5.3.5 CO_2 LASER

This decontamination method utilizes a CO_2 (carbon dioxide) laser to direct an infrared laser light beam onto a contaminated building surface. Surface contamination is thermally decomposed directly, and subsurface contaminants can be thermally decomposed by heat conduction from the irradiated surface. This application is limited to line-of-sight locations, and a highly complex beam guidance system is necessary.

6.0 CONTAINMENT

Containment refers to technologies which isolate contaminated materials from clean materials. The purpose of containment is to segregate hazardous constituents from clean materials in order to minimize migration and spread of contaminants. Such technologies as subsurface barriers may be used to stop ground water flow into a zone of hazardous materials or may be used to contain the flow of contaminated ground water from a zone of hazardous materials.

6.1 SUBSURFACE BARRIERS

The term subsurface barriers refers to a variety of methods whereby low-permeability cut off walls or diversions are installed below ground to contain, capture, or redirect ground water flow. The most commonly used subsurface barriers are slurry walls, particularly soil-bentonite (SB) slurry walls. Less common are cement-bentonite (CB) or concrete (diaphragm) slurry walls, grouted barriers, and sheet piling cut offs. Grouting also may be used to create horizontal barriers for sealing the bottom of contaminated sites.

6.1.1 SLURRY WALL

Slurry walls are the most common subsurface barriers because they are a relatively inexpensive means of reducing ground water flow in unconsolidated earth materials. The term slurry wall can be applied to a variety of barriers, constructed in a vertical trench that is excavated under a slurry. This slurry, usually a mixture of bentonite and water, hydraulically shores the trench and forms a filter cake on the trench walls to limit fluid losses. Slurry wall types are differentiated by the materials used for backfill. Most commonly, an engineered soil mixture is blended with the bentonite slurry to form a SB slurry wall. In some cases, the trench is excavated under a slurry of Portland cement, bentonite, and water, and this mixture is left in the trench to harden into a CB slurry wall. In instances where high strength is required of a subsurface barrier, precast or cast-in-place concrete panels are constructed in the trench to form a diaphragm wall.

6.1.2 GROUT CURTAIN

Grout curtains are subsurface barriers created in unconsolidated materials by pressure injection. Various methods of forming a grout curtain are available depending on the depths and geologic materials encountered. Spacing of injection points and placement methods directly affect barrier integrity.

Grout barriers are much more difficult to install than slurry walls and generally are incapable of attaining truly low permeabilities in unconsolidated materials.

6.1.3 SHEET PILING

In addition to slurry wall and grouted curtains, sheet piling can be used to form a ground water barrier. Sheet piles can be made of precast concrete or steel. Concrete is used primarily where great strength is required. Steel is the most effective medium in terms of ground water cut off. However, because of unpredictable wall integrity, steel sheet piling is seldom used except for temporary dewatering for other construction or as erosion protection where some other barrier, such as a slurry wall, intersects ground water.

The primary design parameters for any barrier are permeability and dimensions. Dimensional requirements are based on site characteristics. Depth limitations are governed by the soil material at the site. Design factors for ultimate permeability of the cut off include a factor to account for leakage through the interlocking joints.

6.1.4 BOTTOM SEALING

Bottom sealing refers to techniques used to place a horizontal barrier beneath an existing site to prevent downward migration of contaminants. Most of these techniques involve variations in grouting or other construction support techniques.

Emplacement of a bottom seal by grouting involves drilling through the site, or directional drilling from the site perimeter, and injecting grout to form a horizontal or curved barrier. One such technique, jet grouting, involves

drilling a pattern of holes across the site to the intended barrier depth. A special jet nozzle is lowered, and a high-pressure stream of air and water erodes the soil. By turning the nozzle through a complete rotation, a flat, circular cavity is formed. The cavity is then grouted with intersecting grouted masses forming the barrier. The directional drilling method is similar to curtain grouting except that it is performed in slanted rather than vertical boreholes.

Block displacement is an experimental technique for isolating and raising a contaminated block of earth. By this technique, a perimeter barrier is constructed by slurry trenching or grouting. Grout is then injected into specially notched holes bored through the site. Continued grout or slurry pumping causes displacement of the block of earth isolated by the perimeter barrier and forms a bottom seal beneath the block. This technique has been laboratory tested and field demonstrated only at a nonhazardous waste site.

6.1.5 PNEUMATIC BARRIER

Pneumatic subsurface containment is a newly developing process establishing a positive-pressure air seal to prevent the migration of contaminants across a designated point, creating a pressure gradient to prevent penetration of ground water or leachate. This process has had only limited success and is in the developmental stage.

6.1.6 SYNTHETIC MEMBRANE CUT OFF WALL

Synthetic membranes can be used to form a cut off wall to divert or contain ground water. Compatibility testing of the liners with chemical wastes must be performed to determine durability.

To place a synthetic membrane liner for a vertical ground water barrier, a trench is dug from the surface to an impervious soil layer. A drain is placed in the bottom of the trench to remove excess water. The synthetic membrane is suspended vertically in the trench, and the trench is backfilled with sand or other suitable material.

Synthetic membranes make good ground water cut off barriers if properly installed. The materials are available in a variety of compositions with

documented chemical compatibilities. The membranes are flexible enough to accommodate earth movement or settling.

6.1.7 DYNAMIC DEEP COMPACTION

Dynamic deep compaction is the process of compacting soil by dropping heavy weights from heights. The technique improves the ground stability and decreases permeability up to an effective depth of 100 ft.

Dynamic deep compaction is an alternative to excavation and removal, recompaction, and slurry walls. Successful site improvement using dynamic deep compaction involves accurate predictions of energy and impact spacing requirements, careful control of site operations, and extensive geotechnical testing to verify effectiveness. Remedial experience with dynamic deep compaction is limited.

6.1.8 HYDRAULIC CONTROLS

Movement of groundwater can be controlled or prevented by use of a specially designed extraction system (see Section 1.4.2). If the location and rate of each extraction point is correct, hydraulic gradients can be established in predetermined patterns, usually based on modeling and pilot testing. These gradients can be so arranged to prevent or encourage water movement in a particular direction. This affords opportunities for isolation, dewatering flushing, or other in-situ treatment of soils in selected areas without excavation.

6.2 SUBSURFACE DRAINS

Subsurface drains include any type of buried conduit used to convey and collect aqueous discharges by gravity flow. They create a continuous zone of influence within which ground water flows toward the drain.

Subsurface drains are constructed by placing tile or perforated pipe in a trench, surrounding it with gravel, and backfilling the trench with soil or clay. The drains function as a continuous line of extraction wells, creating a zone of influence that draws ground water toward the drain. The subsurface drain is useful for collecting contaminated ground water at shallow depths.

Pipe drains are used most frequently at hazardous waste sites for conveying flow to a wet well or storage tank. Gravel beds, french drains, and tile drains are used to a more limited extent. At shallow depths, drains are an efficient means of ground water collection relative to extraction. Drains also can be used in conjunction with extraction wells to maximize well efficiency where areas of impermeable soils are present. The primary disadvantage to subsurface drains is that their application is limited to ground water depths of 20-40 ft.

6.3 CAPPING

Capping is used at sites where contaminated materials either are left in place or buried. Capping of such sites eliminates direct contact of contaminated materials by target populations, prevents migration of surficial contamination via runoff, and reduces ground water recharge by limiting infiltration.

6.3.1 SINGLE-LAYERED SOIL

Single-layered soil caps can be constructed of any low-permeability materials. The thickness of soil caps depends on the amount of anticipated settlement and local weather conditions. A temporary cap constructed of clay or natural soil may be used, depending on the length of time before a final remedial response is completed and the areal extent. A single-layered soil cap may also be used where evapotranspiration greatly exceeds precipitation and/or there is a great distance between the waste and the nearest source of usable ground water. In these cases, it may be acceptable to use an extremely low-permeability soil or admix buried by natural soils beneath the frost penetration depth. The overlying soils would also protect the cap from drying and cracking.

6.3.2 MULTIMEDIA

The design of multimedia caps generally conforms to EPA's guidance under RCRA for landfill liner systems and final cover (40 CFR Part 264 Subpart N). The RCRA multimedia cap consists of a low-permeability layer, a drainage

layer, and a vegetative layer. Maintenance of the cap cover must be performed periodically to prevent settlement, erosion, and breaching by deep-rooted vegetation or burrowing animals.

The low-permeability soil liner should have a permeability of less than 10^{-7} centimeters per second (cm/sec), and should be at least two feet thick. The synthetic liner should be placed and seamed according to manufacturers specifications. Tests for adhesion, shear strength, and other tests must be performed as recommended by the liner manufacturer. The drainage layer, which typically is sand or a coarser material, should have a permeability of 10^{-3} cm/sec or greater. The thickness of the drainage layer depends on the expected waste settling. A vegetative layer should be at least a two feet thick to accommodate expected root penetration, and it should be evenly spread and not overly compacted. The thickness of this topsoil layer should be greater than the deepest zone of frost penetration to account for freeze-thaw stresses.

6.3.3 CLAY

The clay cap consists of a low-permeability clay layer overlain by vegetated topsoil. The vegetative cover serves to control moisture, protect the integrity of the clay layer, and prevent erosion. Frequent inspection and maintenance of the clay cap is essential to ensure its integrity.

Clay covers must be kept moist to avoid cracking. Proper moisture levels are maintained by the addition of the topsoil layer. Because clay is susceptible to freeze-thaw stresses, the topsoil must be thick enough to protect the clay from frost.

Clay materials have been used extensively as liners in landfills and offer the advantage of low permeability as a capping material. Design considerations must include a thorough understanding of the interactions between clay and waste constituents because certain chemicals react with and dissolve portions of clay barriers. The lack of secondary containment, such as a synthetic liner, is a potential risk of ground water contamination due to the leaching of contaminants through the clay layer.

6.3.4 SYNTHETIC MEMBRANE LINER

The use of impervious synthetic flexible membrane liners (FML) for capping lagoons and landfills has become widespread in recent years. Membranes are resistant to a wide range of chemicals and bacteria but have limited ability to withstand the stress of heavy machinery, lacerations, and punctures. Since the membrane sheeting is produced in relatively narrow strips, a finished liner requires a large number of seams. The quality of seams is important to the liner success. The performance of a liner is limited by its weakest point.

6.3.5 SURFACE SEALING

Cement, quicklime, or other grouting materials can be applied to, or mixed with bottom sediments to create a seal that minimizes leaching and erosive transport of contaminants.

There are essentially two approaches to sealing or stabilizing bottom sediments. The first is to pneumatically apply a layer of concrete (shotcrete) or grout to form a surface seal. The second method is to mix concrete, quicklime, or a grout with the contaminated sediments to stabilize them. The stabilizing agent is applied to the surface and mixed with the contaminated sediments using rubber-tire or crawler-type rotor or trencher mixing equipment. Stabilize the ground by continuously and uniformly mixing the soft soil with solidification agents. Following completion of the sealing or stabilizing operation, the sediment bottom can be restored to its natural grade and sediment composition.

6.3.6 THERMOPLASTIC

Asphalt cement or other related bituminous membranes, generally one-quarter-inch thick, can be applied as a cover or cap. Asphalt membranes are blown with a hot phosphoric catalyst and are solidified by cooling. Asphalt cement must be produced in a kiln, applied with a paving machine, and compacted by a roller. Asphalt is subject to attack by petroleum distillates and solvents.

6.4 DIVERSION

6.4.1 DIKES AND BERMS

Dikes and berms are earthen ridges which divert runoff away from waste disposal sites to manmade or natural drainageways. This provides isolation of areas from erosion, surface water infiltration, and offsite transport of contaminants by runoff. Standard construction techniques and equipment are used for dikes and berms. The required earth fill may be available onsite. Density of these structures is dependent on the desired functions and site-specific conditions to be addressed. Stabilization required, such as, seeding, mulching, or chemical soil additives, is a function of the design life of the structure. Disadvantages of dikes and berms are the inspections and maintenance required to ensure integrity.

6.4.2 DITCHES AND TRENCHES

Ditches and trenches are excavated drainageways generally of V-shaped, trapezoidal, or parabolic cross-section design. Ditches are temporary structures, where as, trenches are more permanent and can be used with dikes to provide better erosion control.

Ditches and trenches control surface erosion and infiltration at disposal sites by diverting incoming run-on around a site. When placed downslope of a site, ditches and trenches collect and transport contaminated runoff to basins or treatment facilities. Frequent inspection and maintenance requirements are the primary disadvantage of this technology.

6.4.3 TERRACES AND BENCHES

Terraces and benches are embankments constructed along the contour of long or steep slopes to intercept and divert flow and to control erosion by reducing slope length. These structures are classified as bench terraces or drainage benches. Bench terraces are used primarily to reduce land slope. Drainage benches on broad based terraces are used to remove or retain water on sloping land.

Benches and terraces may be used to break up steeply graded slopes of covered disposal sites into less erodible segments. Upslope of disposal sites, benches and terraces slow and divert storm runoff around the site.

Downslope of sites, benches and terraces intercept and divert runoff to basins or treatment facilities. Hence, they may function to hydrologically isolate sites where remedial actions have not yet been completed, to control erosion of cover materials on sites that have been capped, or to collect contaminated runoff from disposal areas. For disposal sites undergoing final grading (after capping and prior to revegetation), construction of benches or terraces may be included as part of the site closure plan.

6.4.4 CULVERTS

Culverts are structures used to carry flows of surface runoff to lower elevations without erosive damage. They discharge the runoff to stabilized outlets and sediment traps.

Culverts are effective in preventing erosion on long, steep slopes. No special materials, equipment, or construction methods are required for installation. Design criteria such as recommended bottom widths, maximum drainage areas, and inlet/outlet design are specified in literature.

6.4.5 LEVEES AND FLOODWALLS

Levees are earthen embankments that function as flood protection structures in areas subject to inundation from tidal flow or stream flooding. Levees create a barrier to confine floodwaters to a floodway and to protect structures behind the barrier. Floodwalls perform the same function as levees but are constructed of concrete.

For hazardous waste sites, levees and floodwalls help to control losses of cover material and waste and prevent massive leachate production and subsequent contamination from stream or tidal flooding.

Flood containment levees are most suitable for installation in flood fringe areas or areas subject to storm tide flooding but not for areas directly within open floodways. They may be constructed as perimeter embankments surrounding disposal sites located in floodplain fringe areas. Levees may also be installed at the base of landfills along slope faces that are subject to periodic inundation.

6.4.6 COFFERDAMS

Cofferdams can be built around a contaminated area in a waterbody to isolate that area from stream flow. The area then can be dredged, dewatered, and excavated or capped with low-permeability material. Cofferdams are most easily constructed for flow containment of shallow ports, streams, and rivers or water with low flow velocities. Where flow velocity exceeds two feet per second (ft/sec), cofferdam construction is not recommended because of the difficulty of driving sheet piling under these conditions. Cofferdam construction is feasible for some relatively wide and deep rivers, providing that the velocity of flow is not excessive.

Cofferdams may be constructed of various materials, including soil, sheet piling, earth-filled sheet pile cells, and sandbags for short-duration structures. Sheet-pile cofferdams are generally constructed of black steel sheeting from 5 to 12 gauge in thickness and from 4 to 40 ft in length.

6.4.7 GRADING AND REVEGETATION

Grading is the general term for techniques used to reshape the surface of covered materials in order to manage surface water infiltration and runoff while controlling erosion. The spreading and compaction steps used in grading are standard construction techniques. The equipment and methods used in grading are essentially the same for all covered surfaces, but applications of grading technology vary by site. Grading is often performed in conjunction with surface sealing practices and revegetation as part of closure plan implementation.

Vegetative cover can help stabilize the surface of hazardous waste disposal sites, especially when preceded by capping and grading. Revegetation decreases erosion by wind and water and contributes to the development of a naturally fertile and stable surface environment. Also, the technique can be used to upgrade the appearance of disposal sites that are being considered for various reuse options. Vegetative stabilization on a semiannual or seasonal basis can also be used as a remedial technique for disposal sites.

6.4.8 CHANNELS AND WATERWAYS

Channels are excavated ditches that are generally wide and shallow with trapezoidal, triangular, or parabolic cross sections. Diversion channels are used primarily to intercept runoff or reduce velocity. They may or may not be stabilized. Channels stabilized with vegetation or stone rip-rap are used to collect and transfer diverted water offsite or to onsite storage or treatment.

Applications and limitations of channels and waterways differ depending on their specific design. Types of channels and waterways vary with respect to drainage area and maximum permissible velocity. Earthen channels can be used on the perimeter of a disposal site to divert run-on away from the waste disposal area.

6.5 VAPOR EMISSION CONTROL

Methods for controlling the release of gaseous emissions to the atmosphere include covers for control of volatile emissions from impoundments or excavations and active gas collection systems for collection and control of gases generated in landfills.

6.5.1 COVERS/CAPS

Covers involve the placement of a barrier at the water-air or soil/air interface to reduce gaseous emissions. Lagoon covers, floating immiscible liquids, floating spheres and suppressant foams can be used for this purpose.

Floating lagoon covers consist of a synthetic lining placed in one piece over an impoundment with proper anchoring at the edges and floats to prevent displacement.

6.5.2 GAS COLLECTION/RECOVERY

An active interior gas collection system alters the pressure gradients and paths of gas migration by mechanical means. It typically consists of gas extraction wells; gas collection headers; vacuum blowers or compressors; and a treatment system.

The centrifugal blowers induce flow from the landfill, which is normally under positive pressure, to the blower intake. Subsurface gases flow in the direction of decreasing pressure gradient through the wells, the header, and the blower and are treated and vented to the atmosphere.

Active interior gas collection/recovery systems are used to collect gases from beneath a landfill surface before they are vented to the atmosphere. They can be installed at virtually any site where it is possible to drill or excavate through the landfilled material to the required depth. Limiting factors could include the presence of free-standing leachate or impenetrable materials within the landfill.

6.6 FUGITIVE DUST CONTROL

Commonly used measures for controlling fugitive dusts from inactive waste piles and active cleanup sites include chemical dust suppressants, wind screens, water spraying, and other dust control measures commonly used during construction. Each is described below.

6.6.1 CHEMICAL SPRAYING

Dust suppressants include a wide range of natural and synthetic waste materials that strengthen bonds between soil particles and hold this strengthened condition for a predictable period of time. A wide variety of resins, bituminous materials or pallatives, and polymers are marketed as dust suppressants.

Chemical dust suppressants are most commonly applied with water wagons equipped with nozzles that shoot a flat spray behind the vehicle at a constant flow. A calibrated spray bar is more suitable for application of chemical dust suppressants. Sophisticated systems exist which allow the operator to specify an application rate and automatically regulate speed and spray rate. Some bitumens must be applied with an asphalt distributor because the material must be heated before application.

Dust suppressants are used primarily to temporarily bind soil particles and reduce fugitive dust emissions. Effectiveness of a dust suppressant depends on maintaining the soil-chemical crust. Emerging weeds and any type of

disturbance from traffic will break this crust. Pre-emergent weed control may be used before applying dust suppressant. If undisturbed, dust suppressants can be expected to be 100 percent effective for a period of 1 to 4 weeks, depending upon the formulation. Control efficiencies decline thereafter. Dust suppressants also may be used to control dust from active work areas, although they are less effective for this application and require frequent reapplication.

6.6.2 WATER SPRAYING

The most commonly used method to control dust emissions is spraying water on exposed surface areas. This method is mainly used to reduce fugitive dusts along active travel paths, within excavation areas, and during material transport.

Active travel areas dry quickly, and water must be reapplied frequently to maintain effectiveness. Water is applied with a water wagon or spray bar. The quantity will vary with the surface material, sunlight, humidity, and traffic level. The effectiveness of chemical dust suppressants and water spraying along unpaved roads can be improved by compaction and addition of roadway aggregate.

Spraying of soil or other material in a truck box can be accomplished by installing a frame which supports a line of spray nozzles on either side of the length of the truck. Materials then can be sprayed when loaded on the truck and when being dumped. Water spraying is more effective for large grain-size particles, although some control of small particle sizes can be expected. Addition of surfactant to the water can be used to increase control efficiencies and reduce water usage.

Fugitive dust emissions from excavation activities can be reduced by maintaining a favorable slope and orientation on the waste pile. The slope of the pile in the prevailing wind direction should be less than 10 degrees to minimize emissions. Measured wind velocities on slopes greater than 10 degrees will accelerate significantly, and the zone of maximum particle entrainment is at the top of the pile. If the length of a pile is perpendicular to the prevailing wind direction, emissions can be reduced

about 60 percent in comparison to a pile with the length parallel to the wind direction.

6.6.3 WIND FENCES/SCREENS

A wind fence is a porous screen which absorbs wind energy or deflects enough wind that the wind velocity is lowered below the threshold required for initiation of soil movement. Wind screens are typically four to ten feet high and are composed of polyester or other high-strength material.

Wind screens are used to reduce wind velocity and control fugitive dusts. Tests conducted by EPA on the efficiency of wind screens in controlling dust from fly ash stockpiles indicated that they were about 60 percent efficient in controlling inhaleable particulates at wind speeds of about 10 to 13 miles per hour (mph), with gusts of 18 to 19 mph. Control efficiencies for total suspended particulates (TSP) were about 75 percent. Maximum reduction of wind velocity can be expected for a distance of one to five fence heights downstream.

6.7 EXCLUSION

Exclusion involves methods of keeping hazardous source areas secure from wildlife. As an example, placing a fence around Basin F.

6.8 CAPTURE/ENCLOSURE

Capturing wildlife and enclosing it in an area safe from hazardous materials. A fenced area will hold animals while remediation is ongoing nearby.

7.0 RECLAMATION

The action by which areas are returned to their original state prior to contamination and remediation, or are returned to an effectively equivalent state. Reclamation may involve restoration of land, water and biota so that following remediation, the site can be stabilized in order to minimize further deterioration of the environment.

7.1 SITE REHABILITATION

7.1.1 BACKFILLING/REGRADING

Backfilling and regrading are general techniques for reshaping and reclaiming the land surface. Almost any equipment can be used for backfilling and regrading including backhoes, bulldozers, scrapers, and combination backhoe-front-end loader. In order to prevent settling of the backfill after construction, periodic compaction of soil lifts is required. This may be accomplished using air tamping or a vibrating or sheepsfoot compactor.

Regrading has the primary functions of preventing or intercepting run-on/runoff while reducing erosion. Grading is often performed in conjunction with surface sealing practices.

7.1.2 STABILIZATION

Placing protective cover over exposed loose soil in order to prevent erosion. May involve additives and synthetic covers.

7.1.3 RECHARGE

This technique replaces water that is removed for treatment or diverted.

7.1.4 RESALE FOR SCRAP

Resaling of scrap metal is a means of recovering some of the capital costs associated with the initial purchase of the building materials. Resaling also eliminates the need for offsite or onsite disposal thereby lessening the strain on existing landfills.

7.1.5 REUSE BY THE ARMY

Equipment and materials would be reused by the Army.

7.1.6 BUILDING RESTORATION

Buildings would be renovated for reinhabitation or industrial reuse.

7.1.7 REVEGETATION

Revegetation is another general technique for reshaping and reclaiming the land surface. The establishment of a vegetative cover is a cost-effective method of stabilizing the surface of waste disposal sites, especially when preceded by capping and grading. Revegetation decreases erosion by wind and water and contributes to the development of a naturally fertile and stable surface environment. A systematic revegetation plan will include:

- Selection of suitable plant species;
- Seedbed preparation;
- Seeding/planting;
- Mulching and/or chemical stabilization; and
- Fertilization and maintenance.

Revegetation may be part of a long-term site reclamation project, or it may be used on a temporary or seasonal basis to stabilize intermediate cover surfaces at waste disposal sites. Revegetation may not be feasible at disposal sites with high cover soil concentrations of phytotoxic chemicals, unless these sites are properly sealed and vented and then covered with suitable topsoil.

Grasses such as fescue and lovegrass provide a quick and lasting ground cover with dense root systems that anchor soil and enhance infiltration. Legumes store nitrogen in their roots, enhancing soil fertility and assisting the growth of grasses. Legumes are readily established on steep slopes. Shrubs also provide a dense surface cover, and certain species are tolerant of acidic soils. At sites where there is no danger of puncturing an impermeable liner, trees can be planted in the later stages of site reclamation after grasses and legumes have established a stable ground cover. Trees help provide long-term protective cover and build up a stable, fertile layer of decaying leaves and branches. A well-mixed and properly

selected cover of grasses, shrubs, and trees will ultimately restore both economic and aesthetic value to a reclaimed site, providing suitable habitat for populations of both humans and wildlife.

7.1.8 HABITAT RESTORATION/REINTRODUCTION

Habitat restoration refers to the reestablishment of suitable habitat capable of supporting the indigenous wildlife of a site. This can be a very complex undertaking because of the subtle intricacies of the food chain. It applies to both terrestial and aquatic habitats and involves reestablishing plant and animal communities in such a way as to allow the ecosystem to sustain itself in a configuration similar to "pre-disturbance" conditions.

7.2 GROUTING/RELINING

Grouting and/or relining are increasingly popular and sophisticated techniques used for in-place rehabilitation of sewer or water lines. With modern equipment, even badly deteriorated lines can be repaired in place with a minimum of disturbance and good long term results. Grout can be applied directly to the pipe interior by application equipment which travels down the line. In some cases, a preformed or partially formed sleeve is inserted through a manhole or other opening and then physically or chemically formed or fixed in place.

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APPENDIX B

TECHNOLOGY SCREENING

TABLE B-1. TECHNOLOGY SCREENING

ARSENAL - WIDE

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
SOILS/SEWERS (INCLUDES SEDIMENTS AND PIPING)	REMOVAL	1. Demolition	X				
		2. Excavation	X				
		3. Dredging	X				
		4. Pumping	X				
		5. Materials Transport	X				
	DISPOSAL	1. Landfilling	X				
		2. Deep Well Injection	X				
		3. Above Ground Discharge	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Stockpile/Waste Pile	X				
		3. Surface Inpoundment	X				
		4. Drums/Containers/Tanks	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Washing	X				
		2. Solidification and Stabilization	X				
		3. Volatilization (Natural)	X				
		4. Magnetic Separation	X				
		5. Dewatering	X				
		6. Neutralization	X				
		7. Hydrolysis	X				
		8. Ultraviolet Photolysis	X				
		9. Electron Beam	X				
		10. Gamma Irradiation	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				
		Thermal Treatment					
		1. Cryogenics	X				
		2. Evaporation	X				
		3. Thermal Desorption/Volatilization	X				
		4. Surface Flashing/Flaming	X				
		5. Open Burning		X		Physical State	
		6. CO2 Laser	X				
		7. Thermal Oxidation/Incineration	X				
	IN-SITU TREATMENT	Physical/Chemical Treatment					
		1. Solidification and Stabilization	X				

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04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
SOILS/SEWERS (INCLUDES SEDIMENTS AND PIPING)	IN-SITU TREATMENT	Physical/Chemical Treatment					
		2. Vacuum Extraction	X				
		3. Flushing	X				
		4. Venting	X				
		5. Chelation	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				
		Thermal Treatment					
		1. Cryogenics		X			Implementation
		2. Evaporation	X				
		3. Thermal Desorption/Volatilization	X				
		4. CO2 Laser		X			Implementation
	CONTAINMENT	1. Subsurface Barriers	X				
		2. Subsurface Drains	X				
		3. Capping	X				
		4. Diversion	X				
	RECLAMATION	1. Site Rehabilitation	X				
		2. Grouting/Relining	X				
WATER	REMOVAL	1. Pumping	X				
		2. Materials Transport	X				
	DISPOSAL	1. Deep Well Injection	X				
		2. Above Ground Discharge	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Surface Impoundment	X				
		3. Drums/Containers/Tanks	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Solidification and Stabilization	X				
		2. Absorption	X				
		3. Magnetic Separation	X				
		4. Sedimentation	X				

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MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
WATER	DIRECT TREATMENT	Physical/Chemical Treatment					
		5. Flotation/Separation	X				
		6. Filtration/Separation	X				
		7. Dialysis	X				
		8. Electrodialysis	X				
		9. Solvent Extraction	X				
		10. Stripping	X				
		11. Steam Distillation	X				
		12. Adsorption	X				
		13. Neutralization	X				
		14. Precipitation/Flocculation	X				
		15. Chelation	X				
		16. Hydrolysis	X				
		17. Oxidation/Reduction	X				
		18. Chemical Dehalogenation	X				
		19. Ultraviolet Photolysis	X				
		20. Electron Beam	X				
		21. Gamma Irradiation	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				
		Thermal Treatment					
		1. Evaporation	X				
		2. Thermal Desorption/Volatilization	X				
		3. Thermal Oxidation/Incineration	X				
	IN-SITU TREATMENT	Physical/Chemical Treatment					
		1. Solidification and Stabilization	X				
		2. Adsorption	X				
		3. Neutralization	X				
		4. Precipitation/Flocculation	X				
		5. Chelation	X				
		6. Hydrolysis	X				
		7. Oxidation/Reduction	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				

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04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
WATER	IN-SITU TREATMENT	Thermal Treatment					
		1. Evaporation	X				
		2. Thermal Desorption/Volatilization	X				
	CONTAINMENT	1. Subsurface Barriers	X				
		2. Subsurface Drains	X				
		3. Capping	X				
		4. Diversion	X				
	RECLAMATION	1. Site Rehabilitation	X				
BUILDINGS (INCLUDES PROCESS PIPING AND TANKS)	REMOVAL	1. Demolition	X				
		2. Excavation	X				
		3. Materials Transport	X				
	DISPOSAL	1. Landfilling	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Stockpile/Waste Pile	X				
		3. Drums/Containers/Tanks	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Washing	X				
		2. Vacuum Dusting	X				
		3. Hydraulic Scour	X				
		4. Mechanical Scour	X				
		5. Acid Etch	X				
		6. Drill/Spall	X				
		7. Scarification	X				
		8. Steam Cleaning	X				
		9. Sealant/Enclosure	X				
		10. Electropolishing	X				
		11. Ultrasound	X				
		12. Solidification and Stabilization	X				
		13. Ultraviolet Photolysis	X				
		14. Electron Beam	X				
		15. Gamma Irradiation	X				

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04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
BUILDINGS (INCLUDES PROCESS PIPING AND TANKS)	DIRECT TREATMENT	Thermal Treatment					
		1. Cryogenics	X				
		2. Thermal Desorption/Volatilization	X				
		3. Surface Flashing/Flaming	X				
		4. Open Burning	X				
		5. Thermal Oxidation/Incineration	X				
		6. CO2 Laser	X				
	IN-SITU TREATMENT	Physical/Chemical Treatment					
		1. Vacuum Dusting	X				
		2. Hydraulic Scour	X				
		3. Mechanical Scour	X				
		4. Acid Etch	X				
		5. Drill/Spall	X				
		6. Scarification	X				
		7. Steam Cleaning	X				
		8. Sealant/Enclosure	X				
		Thermal Treatment					
		1. Cryogenics	X				
		2. Thermal Desorption/Volatilization	X				
		3. Thermal Oxidation/Incineration	X				
		4. CO2 Laser	X				
	CONTAINMENT	1. Capping	X				
	RECLAMATION	1. Site Rehabilitation	X				
AIR	REMOVAL	1. Elimination of Source	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Adsorption	X				
		2. Scrubbing	X				
		3. Precipitation	X				
		4. Filtration	X				
		5. Afterburners	X				
		6. Gas-Phase Carbon	X				

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04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
AIR	DIRECT TREATMENT	Thermal Treatment					
		1. Thermal Oxidation/Incineration	X				
	CONTAINMENT	1. Vapor Emission Control	X				
		2. Fugitive Dust Control	X				
BIOTA	REMOVAL	1. Selective Elimination	X				
		2. Relocation	X				
	DISPOSAL	1. Landfilling	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Stockpile/Waste Pile	X				
		3. Drums/Containers/Tanks	X				
	CONTAINMENT	1. Exclusion	X				
		2. Capture/Enclosure	X				
	RECLAMATION	1. Site Rehabilitation	X				

* SITE CHARACTERISTICS
Hydrologic Conditions
Geologic Conditions
Site Area/Configuration
Preliminary ARAR's
Physical Conditions

** MATERIAL/CONTAMINANT CHARACTERISTICS
Quantity
Concentration
Chemical Composition
Treatability
Physical State

*** TECHNOLOGICAL LIMITATIONS
Implementation
Operation & Maintanence

SOURCE: ESE, 1988.

NORTH CENTRAL STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
SOILS/SEWERS (INCLUDES SEDIMENTS AND PIPING)	REMOVAL	1. Demolition	X				
		2. Excavation	X				
		3. Dredging	X				
		4. Pumping	X				
		5. Materials Transport	X				
	DISPOSAL	1. Landfilling	X				
		2. Deep Well Injection	X				
		3. Above Ground Discharge	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Stockpile/Waste Pile	X				
		3. Surface Inpoundment	X				
		4. Drums/Containers/Tanks	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Washing	X				
		2. Solidification and Stabilization	X				
		3. Volatilization (Natural)	X				
		4. Magnetic Separation	X				
		5. Dewatering	X				
		6. Neutralization	X				
		7. Hydrolysis	X				
		8. Ultraviolet Photolysis	X				
		9. Electron Beam	X				
		10. Gamma Irradiation	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				
		Thermal Treatment					
		1. Cryogenics	X				
		2. Evaporation	X				
		3. Thermal Desorption/Volatilization	X				
		4. Surface Flashing/Flaming	X				
		5. CO2 Laser	X				
		6. Thermal Oxidation/Incineration	X				
	IN-SITU TREATMENT	Physical/Chemical Treatment					
		1. Solidification and Stabilization	X				

NORTH CENTRAL STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
SOILS/SEWERS (INCLUDES SEDIMENTS AND PIPING)	IN-SITU TREATMENT	Physical/Chemical Treatment					
		2. Vacuum Extraction	X				
		3. Flushing	X				
		4. Venting	X				
		5. Chelation	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				
		Thermal Treatment					
		1. Evaporation	X				
		2. Thermal Desorption/Volatilization	X				
	CONTAINMENT	1. Subsurface Barriers	X				
		2. Subsurface Drains	X				
		3. Capping	X				
		4. Diversion	X				
	RECLAMATION	1. Site Rehabilitation	X				
		2. Grouting/Relining	X				
WATER	REMOVAL	1. Pumping	X				
		2. Materials Transport	X				
	DISPOSAL	1. Deep Well Injection	X				
		2. Above Ground Discharge	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Surface Impoundment	X				
		3. Drums/Containers/Tanks	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Solidification and Stabilization	X				
		2. Absorption	X				
		3. Magnetic Separation	X				
		4. Sedimentation	X				

NORTH CENTRAL STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
WATER	DIRECT TREATMENT	Physical/Chemical Treatment					
		5. Flotation/Separation	X				
		6. Filtration/Separation	X				
		7. Dialysis	X				
		8. Electrodialysis	X				
		9. Solvent Extraction	X				
		10. Stripping	X				
		11. Steam Distillation	X				
		12. Adsorption	X				
		13. Neutralization	X				
		14. Precipitation/Flocculation	X				
		15. Chelation	X				
		16. Hydrolysis	X				
		17. Oxidation/Reduction	X				
		18. Chemical Dehalogenation	X				
		19. Ultraviolet Photolysis	X				
		20. Electron Beam	X				
		21. Gamma Irradiation	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				
		Thermal Treatment					
		1. Evaporation	X				
		2. Thermal Desorption/Volatilization	X				
		3. Thermal Oxidation/Incineration	X				
	IN-SITU TREATMENT	Physical/Chemical Treatment					
		1. Solidification and Stabilization	X				
		2. Adsorption	X				
		3. Neutralization	X				
		4. Precipitation/Flocculation	X				
		5. Chelation	X				
		6. Hydrolysis	X				
		7. Oxidation/Reduction	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				

NORTH CENTRAL STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
WATER	IN-SITU TREATMENT	Thermal Treatment					
		1. Evaporation	X				
		2. Thermal Desorption/Volatilization	X				
	CONTAINMENT	1. Subsurface Barriers	X				
		2. Subsurface Drains	X				
		3. Capping	X				
		4. Diversion	X				
	RECLAMATION	1. Site Rehabilitation	X				
BUILDINGS (INCLUDES PROCESS PIPING AND TANKS)	REMOVAL	1. Demolition	X				
		2. Excavation	X				
		3. Materials Transport	X				
	DISPOSAL	1. Landfilling	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Stockpile/Waste Pile	X				
		3. Drums/Containers/Tanks	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Washing	X				
		2. Vacuum Dusting	X				
		3. Hydraulic Scour	X				
		4. Mechanical Scour	X				
		5. Acid Etch	X				
		6. Drill/Spall	X				
		7. Scarification	X				
		8. Steam Cleaning	X				
		9. Sealant/Enclosure	X				
		10. Electropolishing	X				
		11. Ultrasound	X				
		12. Solidification and Stabilization	X				
		13. Ultraviolet Photolysis	X				
		14. Electron Beam	X				
		15. Gamma Irradiation	X				

TABLE B-2. TECHNOLOGY SCREENING

NORTH CENTRAL STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
BUILDINGS (INCLUDES PROCESS PIPING AND TANKS)	DIRECT TREATMENT	Thermal Treatment					
		1. Cryogenics	X				
		2. Thermal Desorption/Volatilization	X				
		3. Surface Flashing/Flaming	X				
		4. Open Burning	X				
		5. Thermal Oxidation/Incineration	X				
		6. CO2 Laser	X				
	IN-SITU TREATMENT	Physical/Chemical Treatment					
		1. Vacuum Dusting	X				
		2. Hydraulic Scour	X				
		3. Mechanical Scour	X				
		4. Acid Etch	X				
		5. Drill/Spall	X				
		6. Scarification	X				
		7. Steam Cleaning	X				
		8. Sealant/Enclosure	X				
		Thermal Treatment					
		1. Cryogenics	X				
		2. Thermal Desorption/Volatilization	X				
		3. Thermal Oxidation/Incineration	X				
		4. CO2 Laser	X				
	CONTAINMENT	1. Capping	X				
	RECLAMATION	1. Site Rehabilitation	X				
AIR	REMOVAL	1. Elimination of Source	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Adsorption	X				
		2. Scrubbing	X				
		3. Precipitation	X				
		4. Filtration	X				
		5. Afterburners	X				
		6. Gas-Phase Carbon	X				

NORTH CENTRAL STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
AIR	DIRECT TREATMENT	Thermal Treatment					
		1. Thermal Oxidation/Incineration	X				
	CONTAINMENT	1. Vapor Emission Control	X				
		2. Fugitive Dust Control	X				
BIOTA	REMOVAL	1. Selective Elimination	X				
		2. Relocation	X				
	DISPOSAL	1. Landfilling	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Stockpile/Waste Pile	X				
		3. Drums/Containers/Tanks	X				
	CONTAINMENT	1. Exclusion	X				
		2. Capture/Enclosure	X				
	RECLAMATION	1. Site Rehabilitation	X				

* SITE CHARACTERISTICS
Hydrologic Conditions
Geologic Conditions
Site Area/Configuration
Preliminary ARAR's
Physical Conditions

** MATERIAL/CONTAMINANT CHARACTERISTICS
Quantity
Concentration
Chemical Composition
Treatability
Physical State

*** TECHNOLOGICAL LIMITATIONS
Implementation
Operation & Maintanence

SOURCE: ESE, 1988.

EAST STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
SOILS/SEWERS (INCLUDES SEDIMENTS AND PIPING)	REMOVAL	1. Demolition		X	Physical Conditions		
		2. Excavation	X				
		3. Dredging		X	Physical Conditions		
		4. Pumping	X				
		5. Materials Transport	X				
	DISPOSAL	1. Landfilling	X				
		2. Deep Well Injection	X				
		3. Above Ground Discharge	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Stockpile/Waste Pile	X				
		3. Surface Inpoundment	X				
		4. Drums/Containers/Tanks	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Washing	X				
		2. Solidification and Stabilization	X				
		3. Volatilization (Natural)	X				
		4. Magnetic Separation	X				
		5. Dewatering	X				
		6. Neutralization		X		Chemical Composition	
		7. Hydrolysis	X				
		8. Ultraviolet Photolysis	X				
		9. Electron Beam	X				
		10. Gamma Irradiation	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				
		Thermal Treatment					
		1. Cryogenics	X				
		2. Evaporation	X				
		3. Thermal Desorption/Volatilization	X				
		4. Surface Flashing/Flaming	X				
		5. CO2 Laser	X				
		6. Thermal Oxidation/Incineration	X				
	IN-SITU TREATMENT	Physical/Chemical Treatment					
		1. Solidification and Stabilization	X				

EAST STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
SOILS/SEWERS (INCLUDES SEDIMENTS AND PIPING)	IN-SITU TREATMENT	Physical/Chemical Treatment					
		2. Vacuum Extraction	X				
		3. Flushing	X				
		4. Venting	X				
		5. Chelation	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				
		Thermal Treatment					
		1. Evaporation	X				
		2. Thermal Desorption/Volatilization	X				
	CONTAINMENT	1. Subsurface Barriers	X				
		2. Subsurface Drains	X				
		3. Capping	X				
		4. Diversion	X				
	RECLAMATION	1. Site Rehabilitation	X				
		2. Grouting/Relining		X	Physical Conditions		
WATER	REMOVAL	1. Pumping	X				
		2. Materials Transport	X				
	DISPOSAL	1. Deep Well Injection	X				
		2. Above Ground Discharge	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Surface Impoundment	X				
		3. Drums/Containers/Tanks	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Solidification and Stabilization	X				
		2. Absorption	X				
		3. Magnetic Separation	X				
		4. Sedimentation	X				

EAST STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
WATER	DIRECT TREATMENT	Physical/Chemical Treatment					
		5. Flotation/Separation	X				
		6. Filtration/Separation	X				
		7. Dialysis	X				
		8. Electrodialysis	X				
		9. Solvent Extraction	X				
		10. Stripping	X				
		11. Steam Distillation	X				
		12. Adsorption	X				
		13. Neutralization	X				
		14. Precipitation/Flocculation	X				
		15. Chelation	X				
		16. Hydrolysis	X				
		17. Oxidation/Reduction	X				
		18. Chemical Dehalogenation	X				
		19. Ultraviolet Photolysis	X				
		20. Electron Beam	X				
		21. Gamma Irradiation	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				
		Thermal Treatment					
		1. Evaporation	X				
		2. Thermal Desorption/Volatilization	X				
		3. Thermal Oxidation/Incineration	X				
	IN-SITU TREATMENT	Physical/Chemical Treatment					
		1. Solidification and Stabilization	X				
		2. Adsorption	X				
		3. Neutralization	X				
		4. Precipitation/Flocculation	X				
		5. Chelation	X				
		6. Hydrolysis	X				
		7. Oxidation/Reduction	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				

EAST STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
WATER	IN-SITU TREATMENT	Thermal Treatment					
		1. Evaporation	X				
		2. Thermal Desorption/Volatilization	X				
	CONTAINMENT	1. Subsurface Barriers	X				
		2. Subsurface Drains	X				
		3. Capping	X				
		4. Diversion	X				
	RECLAMATION	1. Site Rehabilitation	X				
BUILDINGS (INCLUDES PROCESS PIPING AND TANKS)	REMOVAL	1. Demolition	X				
		2. Excavation	X				
		3. Materials Transport	X				
	DISPOSAL	1. Landfilling	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Stockpile/Waste Pile	X				
		3. Drums/Containers/Tanks	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Washing	X				
		2. Vacuum Dusting	X				
		3. Hydraulic Scour	X				
		4. Mechanical Scour	X				
		5. Acid Etch	X				
		6. Drill/Spall	X				
		7. Scarification	X				
		8. Steam Cleaning	X				
		9. Sealant/Enclosure	X				
		10. Electropolishing	X				
		11. Ultrasound	X				
		12. Solidification and Stabilization	X				
		13. Ultraviolet Photolysis	X				
		14. Electron Beam	X				
		15. Gamma Irradiation	X				

EAST STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
BUILDINGS (INCLUDES PROCESS PIPING AND TANKS)	DIRECT TREATMENT	Thermal Treatment					
		1. Cryogenics	X				
		2. Thermal Desorption/Volatilization	X				
		3. Surface Flashing/Flaming	X				
		4. Open Burning	X				
		5. Thermal Oxidation/Incineration	X				
		6. CO2 Laser	X				
	IN-SITU TREATMENT	Physical/Chemical Treatment					
		1. Vacuum Dusting	X				
		2. Hydraulic Scour	X				
		3. Mechanical Scour	X				
		4. Acid Etch	X				
		5. Drill/Spall	X				
		6. Scarification	X				
		7. Steam Cleaning	X				
		8. Sealant/Enclosure	X				
		Thermal Treatment					
		1. Cryogenics	X				
		2. Thermal Desorption/Volatilization	X				
		3. Thermal Oxidation/Incineration	X				
		4. CO2 Laser	X				
	CONTAINMENT	1. Capping	X				
	RECLAMATION	1. Site Rehabilitation	X				
AIR	REMOVAL	1. Elimination of Source	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Adsorption	X				
		2. Scrubbing	X				
		3. Precipitation	X				
		4. Filtration	X				
		5. Afterburners	X				
		6. Gas-Phase Carbon	X				

EAST STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
AIR	DIRECT TREATMENT	Thermal Treatment					
		1. Thermal Oxidation/Incineration	X				
	CONTAINMENT	1. Vapor Emission Control	X				
		2. Fugitive Dust Control	X				
BIOTA	REMOVAL	1. Selective Elimination	X				
		2. Relocation	X				
	DISPOSAL	1. Landfilling	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Stockpile/Waste Pile	X				
		3. Drums/Containers/Tanks	X				
	CONTAINMENT	1. Exclusion	X				
		2. Capture/Enclosure	X				
	RECLAMATION	1. Site Rehabilitation	X				

* SITE CHARACTERISTICS
Hydrologic Conditions
Geologic Conditions
Site Area/Configuration
Preliminary ARAR's
Physical Conditions

** MATERIAL/CONTAMINANT CHARACTERISTICS
Quantity
Concentration
Chemical Composition
Treatability
Physical State

*** TECHNOLOGICAL LIMITATIONS
Implementation
Operation & Maintanence

SOURCE: ESE, 1988.

TABLE B-4. TECHNOLOGY SCREENING

SOUTH STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
SOILS/SEWERS (INCLUDES SEDIMENTS AND PIPING)	REMOVAL	1. Demolition	X				
		2. Excavation	X				
		3. Dredging	X				
		4. Pumping	X				
		5. Materials Transport	X				
	DISPOSAL	1. Landfilling	X				
		2. Deep Well Injection	X				
		3. Above Ground Discharge	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Stockpile/Waste Pile	X				
		3. Surface Inpoundment	X				
		4. Drums/Containers/Tanks	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Washing	X				
		2. Solidification and Stabilization	X				
		3. Volatilization (Natural)	X				
		4. Magnetic Separation	X				
		5. Dewatering	X				
		6. Neutralization		X		Chemical Composition	
		7. Hydrolysis	X				
		8. Ultraviolet Photolysis	X				
		9. Electron Beam	X				
		10. Gamma Irradiation	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				
		Thermal Treatment					
		1. Cryogenics	X				
		2. Evaporation	X				
		3. Thermal Desorption/Volatilization	X				
		4. Surface Flashing/Flaming	X				
		5. CO2 Laser	X				
		6. Thermal Oxidation/Incineration	X				
	IN-SITU TREATMENT	Physical/Chemical Treatment					
		1. Solidification and Stabilization	X				

SOUTH STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
SOILS/SEWERS (INCLUDES SEDIMENTS AND PIPING)	IN-SITU TREATMENT	Physical/Chemical Treatment					
		2. Vacuum Extraction	X				
		3. Flushing	X				
		4. Venting	X				
		5. Chelation	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				
		Thermal Treatment					
		1. Evaporation	X				
		2. Thermal Desorption/Volatilization	X				
	CONTAINMENT	1. Subsurface Barriers	X				
		2. Subsurface Drains	X				
		3. Capping	X				
		4. Diversion	X				
	RECLAMATION	1. Site Rehabilitation	X				
		2. Grouting/Relining	X				
WATER	REMOVAL	1. Pumping	X				
		2. Materials Transport	X				
	DISPOSAL	1. Deep Well Injection	X				
		2. Above Ground Discharge	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Surface Impoundment.	X				
		3. Drums/Containers/Tanks	X				
	DIRECT TREATMENT	Physical/Chemical Treatment				Quantity	
		1. Solidification and Stabilization	X				
		2. Absorption		X		Quantity	
		3. Magnetic Separation	X				
		4. Sedimentation	X				

SOUTH STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
WATER	DIRECT TREATMENT	Physical/Chemical Treatment					
		5. Flotation/Separation		X		Chemical Composition	
		6. Filtration/Separation	X				
		7. Dialysis	X				
		8. Electrodialysis	X				
		9. Solvent Extraction	X				
		10. Stripping	X				
		11. Steam Distillation	X				
		12. Adsorption	X				
		13. Neutralization		X		Chemical Composition	
		14. Precipitation/Flocculation		X		Chemical Composition	
		15. Chelation		X		Chemical Composition	
		16. Hydrolysis	X				
		17. Oxidation/Reduction	X				
		18. Chemical Dehalogenation	X				
		19. Ultraviolet Photolysis	X				
		20. Electron Beam	X				
		21. Gamma Irradiation	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				
		Thermal Treatment					
		1. Evaporation	X				
		2. Thermal Desorption/Volatilization	X				
		3. Thermal Oxidation/Incineration	X				
	IN-SITU TREATMENT	Physical/Chemical Treatment					
		1. Solidification and Stabilization	X				
		2. Adsorption	X				
		3. Neutralization		X		Chemical Composition	
		4. Precipitation/Flocculation		X		Chemical Composition	
		5. Chelation		X		Chemical Composition	
		6. Hydrolysis	X				
		7. Oxidation/Reduction	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				

SOUTH STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
WATER	IN-SITU TREATMENT	Thermal Treatment					
		1. Evaporation	X				
		2. Thermal Desorption/Volatilization	X				
	CONTAINMENT	1. Subsurface Barriers	X				
		2. Subsurface Drains	X				
		3. Capping	X				
		4. Diversion	X				
	RECLAMATION	1. Site Rehabilitation	X				
BUILDINGS (INCLUDES PROCESS PIPING AND TANKS)	REMOVAL	1. Demolition	X				
		2. Excavation	X				
		3. Materials Transport	X				
	DISPOSAL	1. Landfilling	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Stockpile/Waste Pile	X				
		3. Drums/Containers/Tanks	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Washing	X				
		2. Vacuum Dusting	X				
		3. Hydraulic Scour	X				
		4. Mechanical Scour	X				
		5. Acid Etch	X				
		6. Drill/Spall	X				
		7. Scarification	X				
		8. Steam Cleaning	X				
		9. Sealant/Enclosure	X				
		10. Electropolishing	X				
		11. Ultrasound	X				
		12. Solidification and Stabilization	X				
		13. Ultraviolet Photolysis	X				
		14. Electron Beam	X				
		15. Gamma Irradiation	X				

SOUTH STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
BUILDINGS (INCLUDES PROCESS PIPING AND TANKS)	DIRECT TREATMENT	Thermal Treatment					
		1. Cryogenics	X				
		2. Thermal Desorption/Volatilization	X				
		3. Surface Flashing/Flaming	X				
		4. Open Burning	X				
		5. Thermal Oxidation/Incineration	X				
		6. CO2 Laser	X				
	IN-SITU TREATMENT	Physical/Chemical Treatment					
		1. Vacuum Dusting	X				
		2. Hydraulic Scour	X				
		3. Mechanical Scour	X				
		4. Acid Etch	X				
		5. Drill/Spall	X				
		6. Scarification	X				
		7. Steam Cleaning	X				
		8. Sealant/Enclosure	X				
		Thermal Treatment					
		1. Cryogenics	X				
		2. Thermal Desorption/Volatilization	X				
		3. Thermal Oxidation/Incineration	X				
		4. CO2 Laser	X				
	CONTAINMENT	1. Capping	X				
	RECLAMATION	1. Site Rehabilitation	X				
AIR	REMOVAL	1. Elimination of Source	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Adsorption	X				
		2. Scrubbing	X				
		3. Precipitation	X				
		4. Filtration	X				
		5. Afterburners	X				
		6. Gas-Phase Carbon	X				

SOUTH STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
AIR	DIRECT TREATMENT	Thermal Treatment					
		1. Thermal Oxidation/Incineration	X				
	CONTAINMENT	1. Vapor Emission Control	X				
		2. Fugitive Dust Control	X				
BIOTA	REMOVAL	1. Selective Elimination	X				
		2. Relocation	X				
	DISPOSAL	1. Landfilling	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Stockpile/Waste Pile	X				
		3. Drums/Containers/Tanks	X				
	CONTAINMENT	1. Exclusion	X				
		2. Capture/Enclosure	X				
	RECLAMATION	1. Site Rehabilitation	X				

* SITE CHARACTERISTICS
Hydrologic Conditions
Geologic Conditions
Site Area/Configuration
Preliminary ARAR's
Physical Conditions

** MATERIAL/CONTAMINANT CHARACTERISTICS
Quantity
Concentration
Chemical Composition
Treatability
Physical State

*** TECHNOLOGICAL LIMITATIONS
Implementation
Operation & Maintanence

SOURCE: ESE, 1988.

WEST STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
SOILS/SEWERS (INCLUDES SEDIMENTS AND PIPING)	REMOVAL	1. Demolition	X				
		2. Excavation	X				
		3. Dredging		X	Physical Conditions		
		4. Pumping	X				
		5. Materials Transport	X				
	DISPOSAL	1. Landfilling	X				
		2. Deep Well Injection	X				
		3. Above Ground Discharge	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Stockpile/Waste Pile	X				
		3. Surface Inpoundment	X				
		4. Drums/Containers/Tanks	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Washing	X				
		2. Solidification and Stabilization	X				
		3. Volatilization (Natural)	X				
		4. Magnetic Separation	X				
		5. Dewatering		X	Physical Conditions		
		6. Neutralization		X		Chemical Composition	
		7. Hydrolysis	X				
		8. Ultraviolet Photolysis	X				
		9. Electron Beam	X				
		10. Gamma Irradiation	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				
		Thermal Treatment					
		1. Cryogenics	X				
		2. Evaporation		X	Physical Conditions		
		3. Thermal Desorption/Volatilization	X				
		4. Surface Flashing/Flaming	X				
		5. CO2 Laser	X				
		6. Thermal Oxidation/Incineration	X				
	IN-SITU TREATMENT	Physical/Chemical Treatment					
		1. Solidification and Stabilization	X				

WEST STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
SOILS/SEWERS (INCLUDES SEDIMENTS AND PIPING)	IN-SITU TREATMENT	Physical/Chemical Treatment					
		2. Vacuum Extraction	X				
		3. Flushing	X				
		4. Venting	X				
		5. Chelation	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				
		Thermal Treatment					
		1. Evaporation		X	Physical Conditions		
		2. Thermal Desorption/Volatilization	X				
	CONTAINMENT	1. Subsurface Barriers	X				
		2. Subsurface Drains	X				
		3. Capping	X				
		4. Diversion	X				
	RECLAMATION	1. Site Rehabilitation	X				
		2. Grouting/Relining	X				
WATER	REMOVAL	1. Pumping	X				
		2. Materials Transport	X				
	DISPOSAL	1. Deep Well Injection	X				
		2. Above Ground Discharge	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Surface Impoundment	X				
		3. Drums/Containers/Tanks	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Solidification and Stabilization	X				
		2. Absorption		X		Quantity	
		3. Magnetic Separation	X				
		4. Sedimentation		X		Chemical Composition	

WEST STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
WATER	DIRECT TREATMENT	Physical/Chemical Treatment					
		5. Flotation/Separation	X				
		6. Filtration/Separation	X				
		7. Dialysis	X				
		8. Electrodialysis	X				
		9. Solvent Extraction	X				
		10. Stripping	X				
		11. Steam Distillation	X				
		12. Adsorption	X				
		13. Neutralization		X		Chemical Composition	
		14. Precipitation/Flocculation		X		Chemical Composition	
		15. Chelation		X		Chemical Composition	
		16. Hydrolysis	X				
		17. Oxidation/Reduction	X				
		18. Chemical Dehalogenation	X				
		19. Ultraviolet Photolysis	X				
		20. Electron Beam	X				
		21. Gamma Irradiation	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				
		Thermal Treatment					
		1. Evaporation	X				
		2. Thermal Desorption/Volatilization	X				
		3. Thermal Oxidation/Incineration	X				
	IN-SITU TREATMENT	Physical/Chemical Treatment					
		1. Solidification and Stabilization	X				
		2. Adsorption	X				
		3. Neutralization		X		Chemical Composition	
		4. Precipitation/Flocculation		X		Chemical Composition	
		5. Chelation		X		Chemical Composition	
		6. Hydrolysis	X				
		7. Oxidation/Reduction	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				

WEST STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
WATER	IN-SITU TREATMENT	Thermal Treatment					
		1. Evaporation	X				
		2. Thermal Desorption/Volatilization	X				
	CONTAINMENT	1. Subsurface Barriers	X				
		2. Subsurface Drains	X				
		3. Capping	X				
		4. Diversion	X				
	RECLAMATION	1. Site Rehabilitation	X				
BUILDINGS (INCLUDES PROCESS PIPING AND TANKS)	REMOVAL	1. Demolition	X				
		2. Excavation	X				
		3. Materials Transport	X				
	DISPOSAL	1. Landfilling	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Stockpile/Waste Pile	X				
		3. Drums/Containers/Tanks	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Washing	X				
		2. Vacuum Dusting	X				
		3. Hydraulic Scour	X				
		4. Mechanical Scour	X				
		5. Acid Etch	X				
		6. Drill/Spall	X				
		7. Scarification	X				
		8. Steam Cleaning	X				
		9. Sealant/Enclosure	X				
		10. Electropolishing	X				
		11. Ultrasound	X				
		12. Solidification and Stabilization	X				
		13. Ultraviolet Photolysis	X				
		14. Electron Beam	X				
		15. Gamma Irradiation	X				

TABLE B-5. TECHNOLOGY SCREENING

WEST STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
BUILDINGS (INCLUDES PROCESS PIPING AND TANKS)	DIRECT TREATMENT	Thermal Treatment					
		1. Cryogenics	X				
		2. Thermal Desorption/Volatilization	X				
		3. Surface Flashing/Flaming	X				
		4. Open Burning	X				
		5. Thermal Oxidation/Incineration	X				
		6. CO2 Laser	X				
	IN-SITU TREATMENT	Physical/Chemical Treatment					
		1. Vacuum Dusting	X				
		2. Hydraulic Scour	X				
		3. Mechanical Scour	X				
		4. Acid Etch	X				
		5. Drill/Spall	X				
		6. Scarification	X				
		7. Steam Cleaning	X				
		8. Sealant/Enclosure	X				
		Thermal Treatment					
		1. Cryogenics	X				
		2. Thermal Desorption/Volatilization	X				
		3. Thermal Oxidation/Incineration	X				
		4. CO2 Laser	X				
	CONTAINMENT	1. Capping	X				
	RECLAMATION	1. Site Rehabilitation	X				
AIR	REMOVAL	1. Elimination of Source	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Adsorption	X				
		2. Scrubbing	X				
		3. Precipitation	X				
		4. Filtration	X				
		5. Afterburners	X				
		6. Gas-Phase Carbon	X				

TABLE B-5. TECHNOLOGY SCREENING

WEST STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
AIR	DIRECT TREATMENT	Thermal Treatment					
		1. Thermal Oxidation/Incineration	X				
	CONTAINMENT	1. Vapor Emission Control	X				
		2. Fugitive Dust Control	X				
BIOTA	REMOVAL	1. Selective Elimination	X				
		2. Relocation	X				
	DISPOSAL	1. Landfilling	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Stockpile/Waste Pile	X				
		3. Drums/Containers/Tanks	X				
	CONTAINMENT	1. Exclusion	X				
		2. Capture/Enclosure	X				
	RECLAMATION	1. Site Rehabilitation	X				

* SITE CHARACTERISTICS
Hydrologic Conditions
Geologic Conditions
Site Area/Configuration
Preliminary ARAR's
Physical Conditions

** MATERIAL/CONTAMINANT CHARACTERISTICS
Quantity
Concentration
Chemical Composition
Treatability
Physical State

*** TECHNOLOGICAL LIMITATIONS
Implementation
Operation & Maintanence

SOURCE: ESE, 1988.

TABLE B-6. TECHNOLOGY SCREENING

CENTRAL STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
SOILS/SEWERS (INCLUDES SEDIMENTS AND PIPING)	REMOVAL	1. Demolition	X				
		2. Excavation	X				
		3. Dredging		X	Physical Conditions		
		4. Pumping	X				
		5. Materials Transport	X				
	DISPOSAL	1. Landfilling	X				
		2. Deep Well Injection	X				
		3. Above Ground Discharge	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Stockpile/Waste Pile	X				
		3. Surface Inpoundment		X	Physical Conditions		
		4. Drums/Containers/Tanks	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Washing	X				
		2. Solidification and Stabilization	X				
		3. Volatilization (Natural)	X				
		4. Magnetic Separation	X				
		5. Dewatering		X	Physical Conditions		
		6. Neutralization		X		Chemical Conditions	
		7. Hydrolysis		X		Chemical Conditions	
		8. Ultraviolet Photolysis	X				
		9. Electron Beam	X				
		10. Gamma Irradiation	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				
		Thermal Treatment					
		1. Cryogenics	X				
		2. Evaporation	X				
		3. Thermal Desorption/Volatilization	X				
		4. Surface Flashing/Flaming	X				
		5. CO2 Laser	X				
		6. Thermal Oxidation/Incineration	X				
	IN-SITU TREATMENT	Physical/Chemical Treatment					
		1. Solidification and Stabilization	X				

CENTRAL STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
SOILS/SEWERS (INCLUDES SEDIMENTS AND PIPING)	IN-SITU TREATMENT	Physical/Chemical Treatment					
		2. Vacuum Extraction	X				
		3. Flushing	X				
		4. Venting	X				
		5. Chelation	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				
		Thermal Treatment					
		1. Evaporation	X				
		2. Thermal Desorption/Volatilization	X				
	CONTAINMENT	1. Subsurface Barriers	X				
		2. Subsurface Drains	X				
		3. Capping	X				
		4. Diversion	X				
	RECLAMATION	1. Site Rehabilitation	X				
		2. Grouting/Relining	X				
WATER	REMOVAL	1. Pumping	X				
		2. Materials Transport	X				
	DISPOSAL	1. Deep Well Injection	X				
		2. Above Ground Discharge	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Surface Impoundment	X				
		3. Drums/Containers/Tanks	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Solidification and Stabilization	X				
		2. Absorption	X				
		3. Magnetic Separation	X				
		4. Sedimentation		X		Chemical Composition	

CENTRAL STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
WATER	DIRECT TREATMENT	Physical/Chemical Treatment					
		5. Flotation/Separation	X				
		6. Filtration/Separation	X				
		7. Dialysis	X				
		8. Electrodialysis	X				
		9. Solvent Extraction	X				
		10. Stripping	X				
		11. Steam Distillation	X				
		12. Adsorption	X				
		13. Neutralization	X				
		14. Precipitation/Flocculation	X				
		15. Chelation	X				
		16. Hydrolysis	X				
		17. Oxidation/Reduction	X				
		18. Chemical Dehalogenation	X				
		19. Ultraviolet Photolysis	X				
		20. Electron Beam	X				
		21. Gamma Irradiation	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				
		Thermal Treatment					
		1. Evaporation	X				
		2. Thermal Desorption/Volatilization	X				
		3. Thermal Oxidation/Incineration	X				
	IN-SITU TREATMENT	Physical/Chemical Treatment					
		1. Solidification and Stabilization	X				
		2. Adsorption	X				
		3. Neutralization		X		Chemical Composition	
		4. Precipitation/Flocculation	X				
		5. Chelation	X				
		6. Hydrolysis	X				
		7. Oxidation/Reduction	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				

CENTRAL STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
WATER	IN-SITU TREATMENT	Thermal Treatment					
		1. Evaporation		X		Quantity	
		2. Thermal Desorption/Volatilization	X				
	CONTAINMENT	1. Subsurface Barriers	X				
		2. Subsurface Drains	X				
		3. Capping	X				
		4. Diversion	X				
	RECLAMATION	1. Site Rehabilitation	X				
BUILDINGS (INCLUDES PROCESS PIPING AND TANKS)	REMOVAL	1. Demolition	X				
		2. Excavation	X				
		3. Materials Transport	X				
	DISPOSAL	1. Landfilling	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Stockpile/Waste Pile	X				
		3. Drums/Containers/Tanks	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Washing	X				
		2. Vacuum Dusting	X				
		3. Hydraulic Scour	X				
		4. Mechanical Scour	X				
		5. Acid Etch	X				
		6. Drill/Spall	X				
		7. Scarification	X				
		8. Steam Cleaning	X				
		9. Sealant/Enclosure	X				
		10. Electropolishing	X				
		11. Ultrasound	X				
		12. Solidification and Stabilization	X				
		13. Ultraviolet Photolysis	X				
		14. Electron Beam	X				
		15. Gamma Irradiation	X				

CENTRAL STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
BUILDINGS (INCLUDES PROCESS PIPING AND TANKS)	DIRECT TREATMENT	Thermal Treatment					
		1. Cryogenics	X				
		2. Thermal Desorption/Volatilization	X				
		3. Surface Flashing/Flaming	X				
		4. Open Burning	X				
		5. Thermal Oxidation/Incineration	X				
		6. CO2 Laser	X				
	IN-SITU TREATMENT	Physical/Chemical Treatment					
		1. Vacuum Dusting	X				
		2. Hydraulic Scour	X				
		3. Mechanical Scour	X				
		4. Acid Etch	X				
		5. Drill/Spall	X				
		6. Scarification	X				
		7. Steam Cleaning	X				
		8. Sealant/Enclosure	X				
		Thermal Treatment					
		1. Cryogenics	X				
		2. Thermal Desorption/Volatilization	X				
		3. Thermal Oxidation/Incineration	X				
		4. CO2 Laser	X				
	CONTAINMENT	1. Capping	X				
	RECLAMATION	1. Site Rehabilitation	X				
AIR	REMOVAL	1. Elimination of Source	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Adsorption	X				
		2. Scrubbing	X				
		3. Precipitation	X				
		4. Filtration	X				
		5. Afterburners	X				
		6. Gas-Phase Carbon	X				

CENTRAL STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
AIR	DIRECT TREATMENT	Thermal Treatment					
		1. Thermal Oxidation/Incineration	X				
	CONTAINMENT	1. Vapor Emission Control	X				
		2. Fugitive Dust Control	X				
BIOTA	REMOVAL	1. Selective Elimination	X				
		2. Relocation	X				
	DISPOSAL	1. Landfilling	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Stockpile/Waste Pile	X				
		3. Drums/Containers/Tanks	X				
	CONTAINMENT	1. Exclusion	X				
		2. Capture/Enclosure	X				
	RECLAMATION	1. Site Rehabilitation	X				

* SITE CHARACTERISTICS
Hydrologic Conditions
Geologic Conditions
Site Area/Configuration
Preliminary ARAR's
Physical Conditions

** MATERIAL/CONTAMINANT CHARACTERISTICS
Quantity
Concentration
Chemical Composition
Treatability
Physical State

*** TECHNOLOGICAL LIMITATIONS
Implementation
Operation & Maintanence

SOURCE: ESE, 1988.

NORTH PLANTS STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
SOILS/SEWERS (INCLUDES SEDIMENTS AND PIPING)	REMOVAL	1. Demolition	X				
		2. Excavation	X				
		3. Dredging	X				
		4. Pumping	X				
		5. Materials Transport	X				
	DISPOSAL	1. Landfilling	X				
		2. Deep Well Injection	X				
		3. Above Ground Discharge	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Stockpile/Waste Pile	X				
		3. Surface Inpoundment	X				
		4. Drums/Containers/Tanks	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Washing	X				
		2. Solidification and Stabilization	X				
		3. Volatilization (Natural)	X				
		4. Magnetic Separation	X				
		5. Dewatering	X				
		6. Neutralization	X				
		7. Hydrolysis	X				
		8. Ultraviolet Photolysis	X				
		9. Electron Beam	X				
		10. Gamma Irradiation	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				
		Thermal Treatment					
		1. Cryogenics	X				
		2. Evaporation	X				
		3. Thermal Desorption/Volatilization	X				
		4. Surface Flashing/Flaming	X				
		5. CO2 Laser	X				
		6. Thermal Oxidation/Incineration	X				
	IN-SITU TREATMENT	Physical/Chemical Treatment					
		1. Solidification and Stabilization	X				

NORTH PLANTS STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
SOILS/SEWERS (INCLUDES SEDIMENTS AND PIPING)	IN-SITU TREATMENT	Physical/Chemical Treatment					
		2. Vacuum Extraction	X				
		3. Flushing	X				
		4. Venting	X				
		5. Chelation	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				
		Thermal Treatment					
		1. Evaporation	X				
		2. Thermal Desorption/Volatilization	X				
	CONTAINMENT	1. Subsurface Barriers	X				
		2. Subsurface Drains	X				
		3. Capping	X				
		4. Diversion	X				
	RECLAMATION	1. Site Rehabilitation	X				
		2. Grouting/Relining	X				
WATER	REMOVAL	1. Pumping	X				
		2. Materials Transport	X				
	DISPOSAL	1. Deep Well Injection	X				
		2. Above Ground Discharge	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Surface Impoundment.	X				
		3. Drums/Containers/Tanks	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Solidification and Stabilization	X				
		2. Absorption	X				
		3. Magnetic Separation	X				
		4. Sedimentation	X				

NORTH PLANTS STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
WATER	DIRECT TREATMENT	**Physical/Chemical Treatment**					
		5. Flotation/Separation	X				
		6. Filtration/Separation	X				
		7. Dialysis	X				
		8. Electrodialysis	X				
		9. Solvent Extraction	X				
		10. Stripping	X				
		11. Steam Distillation	X				
		12. Adsorption	X				
		13. Neutralization	X				
		14. Precipitation/Flocculation	X				
		15. Chelation	X				
		16. Hydrolysis	X				
		17. Oxidation/Reduction	X				
		18. Chemical Dehalogenation	X				
		19. Ultraviolet Photolysis	X				
		20. Electron Beam	X				
		21. Gamma Irradiation	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				
		Thermal Treatment					
		1. Evaporation	X				
		2. Thermal Desorption/Volatilization	X				
		3. Thermal Oxidation/Incineration	X				
	IN-SITU TREATMENT	**Physical/Chemical Treatment**					
		1. Solidification and Stabilization	X				
		2. Adsorption	X				
		3. Neutralization	X				
		4. Precipitation/Flocculation	X				
		5. Chelation	X				
		6. Hydrolysis	X				
		7. Oxidation/Reduction	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				

NORTH PLANTS STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
WATER	IN-SITU TREATMENT	Thermal Treatment					
		1. Evaporation	X				
		2. Thermal Desorption/Volatilization	X				
	CONTAINMENT	1. Subsurface Barriers	X				
		2. Subsurface Drains	X				
		3. Capping	X				
		4. Diversion	X				
	RECLAMATION	1. Site Rehabilitation	X				
BUILDINGS (INCLUDES PROCESS PIPING AND TANKS)	REMOVAL	1. Demolition	X				
		2. Excavation	X				
		3. Materials Transport	X				
	DISPOSAL	1. Landfilling	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Stockpile/Waste Pile	X				
		3. Drums/Containers/Tanks	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Washing	X				
		2. Vacuum Dusting	X				
		3. Hydraulic Scour	X				
		4. Mechanical Scour	X				
		5. Acid Etch	X				
		6. Drill/Spall	X				
		7. Scarification	X				
		8. Steam Cleaning	X				
		9. Sealant/Enclosure	X				
		10. Electropolishing	X				
		11. Ultrasound	X				
		12. Solidification and Stabilization	X				
		13. Ultraviolet Photolysis	X				
		14. Electron Beam	X				
		15. Gamma Irradiation	X				

TABLE B-7. TECHNOLOGY SCREENING

NORTH PLANTS STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
BUILDINGS (INCLUDES PROCESS PIPING AND TANKS)	DIRECT TREATMENT	Thermal Treatment					
		1. Cryogenics	X				
		2. Thermal Desorption/Volatilization	X				
		3. Surface Flashing/Flaming	X				
		4. Open Burning	X				
		5. Thermal Oxidation/Incineration	X				
		6. CO2 Laser	X				
	IN-SITU TREATMENT	Physical Treatment					
		1. Vacuum Dusting	X				
		2. Hydraulic Scour	X				
		3. Mechanical Scour	X				
		4. Acid Etch	X				
		5. Drill/Spall	X				
		6. Scarification	X				
		7. Steam Cleaning	X				
		8. Sealant/Enclosure	X				
		Thermal Treatment					
		1. Cryogenics	X				
		2. Thermal Desorption/Volatilization	X				
		3. Thermal Oxidation/Incineration	X				
		4. CO2 Laser	X				
	CONTAINMENT	1. Capping	X				
	RECLAMATION	1. Site Rehabilitation	X				
AIR	REMOVAL	1. Elimination of Source	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Adsorption	X				
		2. Scrubbing	X				
		3. Precipitation	X				
		4. Filtration	X				
		5. Afterburners	X				
		6. Gas-Phase Carbon	X				

TABLE B-7. TECHNOLOGY SCREENING

NORTH PLANTS STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
AIR	DIRECT TREATMENT	Thermal Treatment					
		1. Thermal Oxidation/Incineration	X				
	CONTAINMENT	1. Vapor Emission Control	X				
		2. Fugitive Dust Control	X				
BIOTA	REMOVAL	1. Selective Elimination	X				
		2. Relocation	X				
	DISPOSAL	1. Landfilling	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Stockpile/Waste Pile	X				
		3. Drums/Containers/Tanks	X				
	CONTAINMENT	1. Exclusion	X				
		2. Capture/Enclosure	X				
	RECLAMATION	1. Site Rehabilitation	X				

* SITE CHARACTERISTICS
Hydrologic Conditions
Geologic Conditions
Site Area/Configuration
Preliminary ARAR's
Physical Conditions

** MATERIAL/CONTAMINANT CHARACTERISTICS
Quantity
Concentration
Chemical Composition
Treatability
Physical State

*** TECHNOLOGICAL LIMITATIONS
Implementation
Operation & Maintanence

SOURCE: ESE, 1988.

SOUTH PLANTS STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
SOILS/SEWERS (INCLUDES SEDIMENTS AND PIPING)	REMOVAL	1. Demolition	X				
		2. Excavation	X				
		3. Dredging	X				
		4. Pumping	X				
		5. Materials Transport	X				
	DISPOSAL	1. Landfilling	X				
		2. Deep Well Injection	X				
		3. Above Ground Discharge	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Stockpile/Waste Pile	X				
		3. Surface Inpoundment	X				
		4. Drums/Containers/Tanks	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Washing	X				
		2. Solidification and Stabilization	X				
		3. Volatilization (Natural)	X				
		4. Magnetic Separation	X				
		5. Dewatering	X				
		6. Neutralization	X				
		7. Hydrolysis	X				
		8. Ultraviolet Photolysis	X				
		9. Electron Beam	X				
		10. Gamma Irradiation	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				
		Thermal Treatment					
		1. Cryogenics	X				
		2. Evaporation	X				
		3. Thermal Desorption/Volatilization	X				
		4. Surface Flashing/Flaming	X				
		5. CO2 Laser	X				
		6. Thermal Oxidation/Incineration	X				
	IN-SITU TREATMENT	Physical/Chemical Treatment					
		1. Solidification and Stabilization	X				

SOUTH PLANTS STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
SOILS/SEWERS (INCLUDES SEDIMENTS AND PIPING)	IN-SITU TREATMENT	Physical/Chemical Treatment					
		2. Vacuum Extraction	X				
		3. Flushing	X				
		4. Venting	X				
		5. Chelation	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				
		Thermal Treatment					
		1. Evaporation	X				
		2. Thermal Desorption/Volatilization	X				
	CONTAINMENT	1. Subsurface Barriers	X				
		2. Subsurface Drains	X				
		3. Capping	X				
		4. Diversion	X				
	RECLAMATION	1. Site Rehabilitation	X				
		2. Grouting/Relining	X				
WATER	REMOVAL	1. Pumping	X				
		2. Materials Transport	X				
	DISPOSAL	1. Deep Well Injection	X				
		2. Above Ground Discharge	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Surface Impoundment.	X				
		3. Drums/Containers/Tanks	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Solidification and Stabilization	X				
		2. Absorption	X				
		3. Magnetic Separation	X				
		4. Sedimentation	X				

SOUTH PLANTS STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
WATER	DIRECT TREATMENT	Physical/Chemical Treatment					
		5. Flotation/Separation	X				
		6. Filtration/Separation	X				
		7. Dialysis	X				
		8. Electrodialysis	X				
		9. Solvent Extraction	X				
		10. Stripping	X				
		11. Steam Distillation	X				
		12. Adsorption	X				
		13. Neutralization	X				
		14. Precipitation/Flocculation	X				
		15. Chelation	X				
		16. Hydrolysis	X				
		17. Oxidation/Reduction	X				
		18. Chemical Dehalogenation	X				
		19. Ultraviolet Photolysis	X				
		20. Electron Beam	X				
		21. Gamma Irradiation	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				
		Thermal Treatment					
		1. Evaporation	X				
		2. Thermal Desorption/Volatilization	X				
		3. Thermal Oxidation/Incineration	X				
	IN-SITU TREATMENT	Physical/Chemical Treatment					
		1. Solidification and Stabilization	X				
		2. Adsorption	X				
		3. Neutralization	X				
		4. Precipitation/Flocculation	X				
		5. Chelation	X				
		6. Hydrolysis	X				
		7. Oxidation/Reduction	X				
		Biological Treatment					
		1. Aerobic	X				
		2. Anaerobic	X				

SOUTH PLANTS STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
WATER	IN-SITU TREATMENT	Thermal Treatment					
		1. Evaporation	X				
		2. Thermal Desorption/Volatilization	X				
	CONTAINMENT	1. Subsurface Barriers	X				
		2. Subsurface Drains	X				
		3. Capping	X				
		4. Diversion	X				
	RECLAMATION	1. Site Rehabilitation	X				
BUILDINGS (INCLUDES PROCESS PIPING AND TANKS)	REMOVAL	1. Demolition	X				
		2. Excavation	X				
		3. Materials Transport	X				
	DISPOSAL	1. Landfilling	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Stockpile/Waste Pile	X				
		3. Drums/Containers/Tanks	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Washing	X				
		2. Vacuum Dusting	X				
		3. Hydraulic Scour	X				
		4. Mechanical Scour	X				
		5. Acid Etch	X				
		6. Drill/Spall	X				
		7. Scarification	X				
		8. Steam Cleaning	X				
		9. Sealant/Enclosure	X				
		10. Electropolishing	X				
		11. Ultrasound	X				
		12. Solidification and Stabilization	X				
		13. Ultraviolet Photolysis	X				
		14. Electron Beam	X				
		15. Gamma Irradiation	X				

SOUTH PLANTS STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
BUILDINGS (INCLUDES PROCESS PIPING AND TANKS)	DIRECT TREATMENT	Thermal Treatment					
		1. Cryogenics	X				
		2. Thermal Desorption/Volatilization	X				
		3. Surface Flashing/Flaming	X				
		4. Open Burning	X				
		5. Thermal Oxidation/Incineration	X				
		6. CO2 Laser	X				
	IN-SITU TREATMENT	Physical Treatment					
		1. Vacuum Dusting	X				
		2. Hydraulic Scour	X				
		3. Mechanical Scour	X				
		4. Acid Etch	X				
		5. Drill/Spall	X				
		6. Scarification	X				
		7. Steam Cleaning	X				
		8. Sealant/Enclosure	X				
		Thermal Treatment					
		1. Cryogenics	X				
		2. Thermal Desorption/Volatilization	X				
		3. Thermal Oxidation/Incineration	X				
		4. CO2 Laser	X				
	CONTAINMENT	1. Capping	X				
	RECLAMATION	1. Site Rehabilitation	X				
AIR	REMOVAL	1. Elimination of Source	X				
	DIRECT TREATMENT	Physical/Chemical Treatment					
		1. Adsorption	X				
		2. Scrubbing	X				
		3. Precipitation	X				
		4. Filtration	X				
		5. Afterburners	X				
		6. Gas-Phase Carbon	X				

SOUTH PLANTS STUDY AREA

04-Aug-88

MEDIA	RESPONSE ACTION	TECHNOLOGIES	ACCEPTED	REJECTED	REASON REJECTED: SITE CHARACTERISTICS*	REASON REJECTED: MATERIAL/CONTAMINANT CHARACTERISTICS**	REASON REJECTED: TECHNOLOGICAL LIMITATIONS***
AIR	DIRECT TREATMENT	Thermal Treatment					
		1. Thermal Oxidation/Incineration	X				
	CONTAINMENT	1. Vapor Emission Control	X				
		2. Fugitive Dust Control	X				
BIOTA	REMOVAL	1. Selective Elimination	X				
		2. Relocation	X				
	DISPOSAL	1. Landfilling	X				
	STORAGE	1. Retrievable Monitored Containment Structure (RMCS)	X				
		2. Stockpile/Waste Pile	X				
		3. Drums/Containers/Tanks	X				
	CONTAINMENT	1. Exclusion	X				
		2. Capture/Enclosure	X				
	RECLAMATION	1. Site Rehabilitation	X				

* SITE CHARACTERISTICS
Hydrologic Conditions
Geologic Conditions
Site Area/Configuration
Preliminary ARAR's
Physical Conditions

** MATERIAL/CONTAMINANT CHARACTERISTICS
Quantity
Concentration
Chemical Composition
Treatability
Physical State

*** TECHNOLOGICAL LIMITATIONS
Implementation
Operation & Maintanence

SOURCE: ESE, 1988.

APPENDIX C
COMMENTS AND RESPONSES

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VIII
999 18th STREET - SUITE 500
DENVER, COLORADO 80202-2405

JUN 1 7 1988

Ref: 8HWM-SR

Colonel W. N. Quintrell,
Program Manager
Office of the Program Manager for
Rocky Mountain Arsenal
ATTN: AMXRM-PM
Building E4460
Aberdeen Proving Ground, Maryland 21010-5401

Re: Rocky Mountain Arsenal (RMA), Task 28, Technology Inventory and Screening Draft Final Report, April, 1988

Dear Colonel Quintrell:

We have reviewed the above referenced report and have the enclosed comments. Please contact Mr. Connally Mears at (303) 293-1528, if there are questions on this matter.

Sincerely yours,

Robert Duprey, Director
Hazardous Waste Management Division

Enclosure

cc: Thomas P. Looby, CDH
David Shelton, CDH
Lt. Col. Scott P. Isaacson
Chris Hahn, Shell Oil Company
R. D. Lundahl, Shell Oil Company
Thomas Bick, Department of Justice
David Anderson, Department of Justice
Mike Witt, ESE

GENERAL COMMENTS ON TASK 28
TECHNOLOGY INVENTORY AND SCREENING
DRAFT FINAL REPORT, APRIL, 1988

1. An expanded bibliography inclusive of specific technology references and vendor documents on innovative technologies is needed.

2. It appears premature to reject all treatment technologies for the buildings in the West Study Area and the water in the East Study Area, and to reject the majority of direct treatment technologies of soils and sewers in the West Study Area - that leaves the wrong impression. The process is an interative one and such decisions will need to be revisited as final information on the contamination becomes available.

3. Deep-well injection was proposed as an acceptable water and soils/sewers disposal method. Due to the history of this technique on the Arsenal, the public's response to its selection as an onsite alternative might be negative, despite any technical arguments in its favor.

4. Secure landfills were considered an acceptable disposal option for soil/sewers, buildings, and biota. Both onsite and offsite landfills should continue to be evaluated in the screening process.

U.S. ENVIRONMENTAL PROTECTION AGENCY
COMMENTS ON TASK 28
TECHNOLOGY INVENTORY AND SCREENING
DRAFT FINAL REPORT, APRIL 1988

Comment 1: An expanded bibliography inclusive of specific technology references and vendor documents on innovative technologies is needed.

Response: The bibliography will be expanded to include reference documents for the description of the various technologies. In many cases the descriptions are based on the technical expertise and experience of the U.S. Army contractors, and no specific reference documents were used. The U.S. Environmental Protection Agency (EPA) is sited in instances where technical literature was used as a reference.

Because the technologies were identified and screened in a generic sense, specific vendor information was not identified or collected. Trade journals would be a good source for vendor documents if EPA desires this information.

Comment 2: It appears premature to reject all treatment technologies for the buildings in the West Study Area and the water in the East Study Area, and to reject the majority of direct treatment technologies of soils and sewers in the West Study Area - that leaves the wrong impression. The process is an interactive one and such decisions will need to be revisited as final information on the contamination becomes available.

Response: EPA's comment is noted and the text will be modified to address the comment.

Comment 3: Deep-well injection was proposed as an acceptable water and soils/sewers disposal method. Due to the history of this technique on the Arsenal, the public's response to its selection as an onsite alternative might be negative, despite any technical arguments in its favor.

Response: EPA's comment is noted. At this stage of the Feasibility Study all alternatives must be considered. For this reason, deep well injection on and offsite of RMA is included as an available technology. Onsite deep well injection is rejected in the screening process, however, offsite deep well injection is accepted, so the technology is accepted.

Comment 4: Secure landfills were considered an acceptable disposal option for soil/sewers, buildings, and biota. Both onsite and offsite landfills should continue to be evaluated in the screening process.

Response: EPA's comment is noted, and landfills will continue to be evaluated in the screening process.

29 JUN RECD

STATE OF COLORADO

COLORADO DEPARTMENT OF HEALTH
4210 East 11th Avenue
Denver Colorado 80220
Phone (303) 320-8333

Roy Romer
Governor

Thomas M. Vernon, M.D.
Executive Director

June 17, 1988

Mr. Donald Campbell
Department of the Army
Program Manager's Office
RMA Contamination Cleanup
AMXRM-EE, Building E4585
Aberdeen Proving Ground, MD 21010-5401

RE: Task 28 Draft Final Report Technology Inventory and Screening

Dear Mr. Campbell:

The State submits the following comments regarding the Task 28 Technology Inventory and Screening Draft Final Report. The State believes that the report has adequately identified the universe of technologies and alternatives for remediation of the impacted media on the Arsenal.

However, the State has three major concerns with the initial screening of technologies conducted.

1. As the State indicated during the Feasibility Study meeting held on May 26, 1988 at the Arsenal, the discussion in the report of the screening criteria employed Arsenal-wide is overly generic. A more comprehensive explanation of those criteria should be included in the report.

2. A description of all specific screening criteria, specific characteristics of each study area, and any assumptions used to eliminate technologies for every medium in each study area must be included in the text. For example:

DCR# 88-01425 - 1/2

a. All technologies for the remediation of the groundwater in the eastern study area were eliminated without any explanation of the rationale used to achieve this result. Eliminating all technologies, selecting a "no action" alternative prior to completing the remedial investigation, and doing so in the initial screening stage of the FS is inconsistent with the Comprehensive Environmental Response, Compensation and Liability Act ("CERCLA"), as amended, and the National Oil and Hazardous Substances Contingency Plan ("NCP").

b. All technologies for the remediation of the buildings in the western study area were eliminated with the exception of "site rehabilitation". Again, no explanation of the rationale used to reach this conclusion is presented. The report must include the assumptions incorporated in determining that the buildings in the western study area should be "rehabilitated" rather than removed.

3. As the State has previously noted, prior to conducting the initial screening of technologies, chemical specific ARARs, initial action levels and preliminary response objectives should be identified for each study area and incorporated into the initial screening process. As discussed at the May 26, 1988 FS meeting, location specific ARARs must also be identified and incorporated into the initial screening of remedial technologies. Failure to do so will likely require a reevaluation of all technologies eliminated once these criteria are defined. A preliminary list of the location specific ARARs identified by the State is attached.

Page 1-1 of the Report states that "[i]nformation was drawn from a number of sources, . . ." These sources or reference materials should be identified and made available so that all parties are using the same set of references to conduct and review FS activities.

In summary, additional information regarding screening criteria used and conclusions which appear to have been drawn based on the screening performed, should be included in the report.

If you have any questions, please contact Jeff Edson with this Division.

Sincerely yours,

David C. Shelton
Director, Hazardous Materials
and Waste Management Division

pc: Michael R. Hope, Deputy Attorney General
David L. Anderson, Esq.
Chris Hahn, Shell Oil Co.
Edward J. McGrath, Esq., HRO
Michael Gaydosh, Esq., EPA
Connally Mears, EPA

LOCATION SPECIFIC ARARS

A. National Historic Preservation Act - 16 U.S.C. Sec. 470; 40 CFR Sec. 6.301(b); 36 CFR Part 800; and C.R.S. Secs. 24-80-201, 24-80.1-101, *et seq*.

Requires federal agencies to take into account the effect of any federally assisted undertaking or licensing on any district, site, building, structure, or object that is included in the National Register of Historic Places.

B. Archeological and Historic Preservation Act - 16 U.S.C. Sec. 469 and 40 CFR Sec. 6.301(c).

Establishes procedures to provide for preservation of historical and archeological data which might be destroyed through alteration of terrain as a result of a federal construction project or a federally licensed activity or program.

C. Historic Sites, Buildings Antiquities Act - 16 U.S.C. Secs. 461-267; 40 CFR Sec. 6.301(a); C.R.S. Secs. 24-80-201, 202, and 211; and C.R.S. Secs. 24-80.1-101, 102, 103, 104 and 108.

Requires federal agencies to consider the existence of location of landmarks on the National Registry of Natural Landmarks to avoid undesirable impacts on such landmarks.

D. Fish and Wildlife Coordination Act - 16 U.S.C. Secs. 661-666 and 40 CFR Sec. 6.302(g).

Requires consultation when federal department or agency proposes or authorizes any modification of any stream or other water body and adequate provision for protection of fish and wildlife resources.

E. Endangered Species Act - 16 U.S.C. Secs. 1531-1543; 50 CFR Parts 17, 402; 40 CFR Sec. 6.302(h); and C.R.S. Secs. 33-2-101, *et seq*.

Requires that federal agencies ensure that any action authorized, funded, or carried out by the agency is not likely to jeopardize the continued existence of any threatened or endangered species or destroy or adversely

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modify critical habitat.

F. Colorado Wildlife Enforcement and Penalties - C.R.S. Secs. 33-1-101, _et seq_.

Prohibits actions detrimental to wildlife.

G. Wildlife Commission Regulations - 2 CCR 406-0.

Establishes specific requirements for protection of wildlife.

H. Executive Order on Protection of Wetlands - Exec. Order No. 11,990 and 40 CFR Sec. 6.302(a) and Appendix A.

Requires federal agencies to avoid, to the extent possible, the adverse impacts associated with the destruction or loss of wetlands and to avoid support of new construction in wetlands if a practicable alternative exists.

I. Executive Order on Floodplain Management - Exec. Order No. 11,988 and 40 CFR Sec. 6.302(b) and Appendix A.

Requires federal agencies to evaluate the potential effects of actions they may take in a floodplain to avoid, to the maximum extent possible, the adverse impacts associated with direct and indirect development of a floodplain.

J. Solid Waste Disposal Act

1. Guidelines for the Thermal Processing of Solid Wastes- 42 U.S.C. Sec. 6901 _et seq_. and 40 CFR Part 240.

   Prescribes guidelines for thermal processing of solid wastes.

2. Guidelines for the Land Disposal of Solid Wastes - 42 U.S.C. Sec. 6901 _et seq_.; 40 CFR Part 241; C.R.S. 30-20-101 _et seq_.; and 6 CCR 1007-2.

   Establishes requirements and procedures for land disposal of solid wastes.

3. Criteria for Classification of Solid Waste Disposal Facilities and Practices - 42 U.S.C. Sec. 6901 _et seq_. and 40 CFR Part 257.

   Establishes criteria for use in determining which solid waste disposal facilities and practices pose a

reasonable probability of adverse effects on health or the environmental and thereby constitute prohibited open dumps.

K. Criteria for the Siting of Hazardous Waste Facilities - 42 U.S.C. Sec. 6901 _et seq_.; 40 CFR Parts 264, 270; C.R.S. 25-15-101 _et seq_.; 6 CCR 1007-2.

Establishes geologic and hydrologic siting criteria through the isolation of wastes from potential exposure pathways for 1000 years to assure short and long term protection of human health and the environment.

L. Criteria for the Location of Hazardous Waste Facilities - 42 U.S.C. Sec. 6901 _et seq_.; 40 CFR Parts 264, 270; C.R.S. 25-15-101 _et seq_.; 6 CCR 1007-3, Part 260, Subpart A and 264.

Prohibits the siting of a hazardous waste facility in the immediate vicinity of recent faulting. Prohibits hazardous waste disposal within the 100 year floodplain. Prohibits the disposal of hazardous waste into surface water and below the groundwater table.

M. Colorado Air Quality Control Act - C.R.S. Secs. 25-7-101 _et seq_. and 5 CCR 1001-2, 1001-3, 1001-4, 1001-5, 1001-8, 1001-9, 1001-10, and 1001-14.

Establishes standards for air quality protection, based on site location within designated nonattainment areas.

N. Colorado Water Quality Control Act - C.R.S. Secs. 25-8-202, 702 and 5 CCR 1002-12.

Requires Water Quality Control Division approval of the locations of wastewater treatment facilities, before commencing construction. Establishes siting criteria relative to floodplains and natural hazards.

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**STATE OF COLORADO
COMMENTS ON TASK 28
TECHNOLOGY INVENTORY AND SCREENING
DRAFT FINAL REPORT, APRIL 1988**

Comment 1: As the State indicated during the Feasibility Study meeting held on May 26, 1988 at the Arsenal, the discussion in the report of the screening criteria employed Arsenal-wide is overly generic. A more comprehensive explanation of those criteria should be included in the report.

Response: The discussion in the Technology Inventory and Screening (TIS) Report regarding screening criteria is adequate for the purposes of this evaluation and screening. As more site-specific information becomes available and the Feasibility Study proceeds, additional screening will be done and more detailed evaluations of technologies will be performed. At this time the evaluation/screening criteria will be more fully explained, and evaluated in the organizations and state OAS review process.

Comment 2: A description of all specific screening criteria, specific characteristics of each study area, and any assumptions used to eliminate technologies for every medium in each study area must be included in the text. For example:

a. All technologies for the remediation of the groundwater in the eastern study area were eliminated without any explanation of the rationale used to achieve this result. Eliminating all technologies, selecting a "no action" alternative prior to completing the remedial investigation, and doing so in the initial screening stage of the FS is inconsistent with the Comprehensive Environmental Response, Compensation and Liability Act ("CERCLA"), as amended, and the National Oil and Hazardous Substances Contingency Plan ("NCP").

b. All technologies for the remediation of the buildings in the western study area were eliminated with the exception of "site rehabilitation". Again, no explanation of the rationale used to reach this conclusion is presented. The report must include the assumptions incorporated in determining that the buildings in the western study area should be "rehabilitated" rather than removed.

<u>Response</u>: The TIS Report will be modified to reflect the State's concern. Specifically, technologies will be considered for remediation of ground water in the Eastern Study Area and buildings in the Western Study Area.

<u>Comment 3</u>: As the State has previously noted, prior to conducting the initial screening of technologies, chemical specific ARARs, initial action levels and preliminary response objectives should be identified for each study area and incorporated into the initial screening process. As discussed at the May 26, 1988 FS meeting, location specific ARARs must also be identified and incorporated into the initial screening of remedial technologies. Failure to do so will likely require a reevaluation of all technologies eliminated once these criteria are defined. A preliminary list of the location specific ARARs identified by the State is attached.

Page 1-1 of the Report states that "[i]nformation was drawn from a number of sources...." These sources or reference materials should be identified and made available so that all parties are using the same set of references to conduct and review FS activities.

In summary, additional information regarding screening criteria used and conclusions which appear to have been drawn based on the screening performed, should be included in the report.

<u>Response</u>: The State's comments are noted. In order to avoid delay of the initial screening of technologies, chemical and location specific ARARs were not included in the screening process contained in this TIS Report. However, a preliminary evaluation of location specific ARARs indicated that they would have no effect on the technology screening. Chemical specific ARARs will be evaluated at a later stage of the FS process. In the future, however, the ARARs will be reviewed and the technologies may be reevaluated to consider the ARARs.

<u>References</u>: The references referred to on Page 1-1 are, in many cases, EPA publications. In most instances, the sources of technical information were the U. S. Army's contractors who have expertise and experience with the technologies. The bibliography to the TIS Report will be expanded to include appropriate references.

Shell Oil Company

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June 16, 1988

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for Rocky Mountain Arsenal
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Dear Mr. Campbell:

Enclosed herewith are Shell Oil's comments on Draft Final Report "Technology Screening and Inventory", Task No. 28, April, 1988.

Sincerely,

R. D. Lundahl
Manager Technical
Denver Site Project

RDL:ajg

Enclosure

cc: (w/enclosure)
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SHELL OIL COMPANY
COMMENTS ON TASK 28
TECHNOLOGY INVENTORY AND SCREENING
DRAFT FINAL REPORT, APRIL 1988

General Comments

Comment 1: In Shell's comments on the Draft Technical Program Plan submitted by letter dated January 6, 1988, we made the following comment:

> "...there is a crucial lack of credible attention given to the importance of screening from further consideration those remedial options with respect to which the incremental costs bear inadequate relationship to their incremental effectiveness. For example, the concept of cost screening on page 2-34 is calculated to produce a remedy which bears little demonstrable connection between human health and environmental protection and cost."

At the SAPC meeting on March 10, 1988, R. G. Dillard reemphasized Shell's concern.

In a recent interview with Inside EPA, J. Winston Porter was quoted as urging early consideration of cost in the RI/FS process rather than deferring cost considerations to the end of the process.

Shell's statements and the concern attributed to Dr. Porter suggest that at this early stage of the "Technology Screening and Inventory", careful and determined effort should be made to reduce the scope and complexity of the inventory and its associated costs so that the remedial technologies that do appear to have real rather than theoretical possibilities of application can become the focus of the RI/FS process.

Response: Shell's concerns that efforts should be made to eliminate cost-ineffective remedial options are noted. However, consistent with EPA guidance, the Technology Inventory and Screening (TIS) is not the stage at which technologies are eliminated based upon cost.

The primary intent of the TIS Report is to list the available technologies that may be used in development of anticipated remedial actions at RMA. The screening step is an initial attempt to eliminate those technologies which are obviously inappropriate at RMA. As more RI/EA information becomes available, the inventory of technologies will be carefully screened

according to site and remedial technologies will be screened according to material/contaminant characteristics, and according to technological limitations. Remedial alternatives will be developed from the accepted technologies and, at this stage, an evaluation of cost-effectiveness will be performed, and inappropriate alternatives will be eliminated.

Specific Comments

Table 2.0-1

Comment 1a: Page 2-4	Other disposal methods for Soils/Sewers are Industrial Landfill and Backfill. Onsite and Offsite would seem to be subsets under Technologies rather than listings under Processes.
Response:	Industrial Landfill and Backfill will be added to the list of available technologies and processes. Onsite and Offsite were included under processes for the sake of convenience. They will remain in this category unless there is strong opposition.
Comment 1b: Page 2-6	Two in-situ thermal desorption processes for soils/sewers are microwave heating and steam injection. Radio-frequency heating is a thermal desorption method, not a thermal oxidation/incineration method. Other thermal treatment methods are direct flame and infrared radiant heating.
Response:	These processes will be included in the tables and text.
Comment 1c: Page 2-8 Item 18	Change "reverse osmosis/membrane separation" to "membrane separation", then list a) reverse osmosis, b) ultrafiltration, and c) microfiltration as processes. On the same page add "electrodialysis" after "dialysis" at item 22. Delete "ultrafiltration" from item 23. Same applies to page 4-2, 4-4, 4-8, 4-10, 4-12, 4-14, 4-16.
Response:	These comments are noted, and the tables and text will be modified.
Comment 1d: Page 2-9	Another in-situ thermal treatment for water is steam injection.
Response:	Steam injection will be included in in-situ thermal treatment.

Comment 1e: Page 2-10	Another method for capping is clay.
	Another option for disposal of buildings is an industrial landfill.
Response:	Clay caps are considered for soil/sewers. Industrial landfill disposal will be included for buildings.
Comment 1f: Page 2-13	Add "thermal catalytic oxidation" as a direct treatment technology for air. This technology has been widely used for destroying organic vapors such as BTX. Same should be added to page 4-2 in "Physical Treatment" under "Air".
Response:	Thermal catalytic oxidation will be added as a thermal oxidation treatment for airborne contaminants.
Comment 2: Page 2-15, Table 2.0-2	Add the following Innovative Technologies/Processes to this list:

ELECTRODIALYSIS
This is a separation process applicable to removing dissolved salts from water. Salts can be concentrated in a small stream (brine) for further volume reduction and final disposal. This process can be applied to groundwater cleanup or coupled with soil washing for salt removal.

ORGANIC SOLVENT EXTRACTION FOLLOWED BY SODIUM METAL DEHALOGENATION OR UV PHOTOLYSIS
These two processes are applicable to contaminated media containing primarily halogenated organics. Sodium metal has been used for dechlorinating PCBs in transformer oil. Photolytic dehalogenation by UV light in organic solvents is also a viable process.

ORGANIC SOLVENT EXTRACTION FOLLOWED BY SUPEROXIDE TREATMENT
Superoxide can be produced electrochemically and used in aprotic organic solvents for degrading refractory organic pollutants. Complete mineralization is achievable for chlorinated pesticides. The process chemistry was developed at Texas A&M University and has received wide attention in recent months.

IN-SITU MICROWAVE HEATING
Microwave (i.e., 0.3-3 GHz) is effective in desorbing semivolatile and nonvolatile organics from contaminated soils. Mobile systems can be built for decontaminating large areas to a depth of one to several feet. Water vapor serves as a carrier for desorbed organics. The

vapor can be collected, treated, and the water could be reused.

IN-SITU RADIO FREQUENCY HEATING
This process is similar to microwave heating in terms of desorption but the power intensity per volume of soil is smaller. The radio frequency (i.e., 1-100MHz) can reach a depth of greater than 10 feet and is suitable for decontaminating hot spots. The desorbed vapor can be collected by suction and further treated.

SOIL WASHING WITH WATER TREATMENT AND RECYCLE
This general process consists of a soil washing operation and a water treatment operation. Sonication and biodegradable detergents can be used for washing organics out of soils. The wash water can then be treated biologically and/or by activated carbon and then recycled.

Response: Electrodialysis, microwave heating soil washing/flushing and radio frequency heating will be included in the list of innovative technologies and process. However, organic solvent extraction followed by sodium metal dehalogenation or UV photolysis, and organic solvent extraction followed by superoxide treatment will not be added to the list as these are essentially complete remedial alternatives and not individual technologies or processes. The differentiation between technologies/processes and remedial alternatives is important and is explained in the Task 28 Technical Plan.

Comment 3:
Page A-1-1

As a general comment, the technology descriptions should each include both advantages and disadvantages to the technology. Current treatment is inconsistent, with some descriptions having only advantages, some descriptions having only disadvantages, some having both, and some having neither.

Also, it should be noted that this list is a combination of technology and process descriptions.

Response: Additional information has been added to a number of technologies and processes. However, it is inappropriate at this stage of the FS process to force a listing of advantages and disadvantages for each technology or process. Because there is not complete site-specific information at this time, it may be inappropriate to assume that a technology may have specific advantages or disadvantages relative to RMA.

Appendix A will be referred to as technology and process descriptions.

Comment 4:
Page A-1-2

Another disadvantage to excavation is the definite boundary of the treatment zone - there is not "spill-over" of treatment past the edges of the excavation. This could lead to conservatism in determining the extent of excavation to meet agreed upon standards which could unduly increase the quantity of soil for further treatment.

Response:

The disadvantage of excavation leading to possible over-excavation is noted as an administrative problem rather than a mechanical problem associated with excavation.

Comment 5:
Appendix A
Page A-2-2
Section 2.3

Change the third sentence to: "Experience with deep well injection of hazardous waste has been obtained primarily from commercial and industrial operations injecting acidic wastes and waste brines of uniform characteristics, respectively.

Response:

The change will be incorporated.

Comment 5a:
Page A-4-6
Section 4.1.11

Solvent extraction has been demonstrated full-scale at a hazardous waste site at a CERCLA site in Savannah, Georgia. Also, in most solvent extraction systems the spent solvent is regenerated and recycled, so that the only material to be disposed of is the "neat" toxic material which has been extracted from the waste, and the "clean" residue.

Response:

The change is noted and will be incorporated.

Comment 5b:
Page A-4-9
Section 4.1.17.2

Where does "recovered solvent" come from? This section needs some clarification.

Response:

The recovered solvent or organic contamination would be recovered or concentrated by processing the contaminated steam effluent. This clarification will be incorporated.

Comments 5c:
Page A-4-9
Section 4.1.18

Osmosis is the spontaneous flow of water from a dilute solution to a more concentrated solution.

Actually, RO increases the concentrations of dissolved solids and miscible liquids.

Fouling of RO membranes won't necessarily be caused by rapidly changing influent properties, but rather by any large change (slow or rapid) in certain of the influent properties, specifically suspended solids or separate phase organics.

Response: The change is noted and will be incorporated.

Comment 5d: Page A-4-11 Section 4.1.20

In the third bullet, solidification and stabilization do not alter the toxicity of a constituent.

Response: Solidification/stabilization may alter toxicity if a waste material is treated so as to chemically change the toxic chemicals in the waste. However, in general solidification/stabilization reduces mobility rather than toxicity.

Comment 5e: Page A-4-16 Section 4.1.25

Water from dewatering can generally be treated in conventional wastewater treatment systems.

Response: The comment is noted and will be incorporated.

Comment 5f: Page A-4-20 Section 4.1.40

Electrostatic precipitation only works if particulates are of a composition that can accept a charge.

Response: The comment is noted and will be incorporated.

Comment 5g: Page A-4-21 Section 4.1.43

Another adsorbent which can be used for air pollution control is a molecular sieve.

Response: The comment is noted, and molecular sieve will be added as an adsorbtion process.

Comment 5h: Page A-4-22 Section 4.2.1

Landfarming can be an in-situ treatment, and it started long before 1970.

Response: The comment is noted and will be incorporated.

Comment 6: Page A-4-22

Add: 4.1.4.4 - Thermal Catalytic Oxidation. This process has been used for the destruction of organic vapors at low to medium temperature with metal or metal oxide catalysts. Catalysts and processes are available for emission control. Aromatics such as benzene, toluene, xylene, ethylbenzene, and organic halides can be destroyed by this method.

Response: This addition is appropriate and will be incorporated.

Comment 7:
Page A-4-22
Section 4.2.1.1

Recent data indicate that chlorinated hydrocarbons can be degraded and completely detoxified by microbial system.

At high concentrations, almost all organic materials are toxic and inhibit microbial activity.

Response: This addition is appropriate and will be incorporated.

Comment 8:
Page A-4-23
Section 4.2.1.4

Aerobic organisms may be able to degrade halogenated aliphatics.

Response: This comment is noted and will be incorporated.

Comment 9:
Page A-4-24
Section 4.2.1.7

Add: "Pure oxygen has also been used in enclosed systems for enhancing oxygen transfer and reducing organic vapor emission."

Response: This addition is appropriate and will be incorporated.

Comment 10:
Page A-4-29
Section 4.3.3.2

Ash from wastes will only fuse if the hearth is operated at a temperature above the ash slagging temperature.

Response: This comment is noted and will be incorporated.

Comment 11:
Page A-4-34
Section 4.3.3.14

What is the plasma made from? Where does the coal come from?

Response: Microwave plasma and microwave heating are the same technologies. The plasma is made up of ions and electrons which collide with other molecules. Coal will be excluded from this description.

Comment 12:
Page A-4-35
Section 4.3.3.15

Move 4.3.3.15 "Radio-Frequency Heating" to page A-4-37 under 4.3.8 and retitle it: "Radio-Frequency Desorbtion".

Response: This change will be made.

Comment 13: Page A-4-35 Section 4.3.3.18	Vendors names should be deleted.
Response:	This change will be made.
Comment 14: Page A-4-35 Section 4.3.8	This section is redundant to 4.3.7.
Response:	This comment is noted and the text will be changed accordingly.
Comment 15: Page A-4-35	Add "Microwave Desorption" and the following description: Microwave (i.e., 0.3-3 GH_z) is effective in desorbing high boiling point organics from soils. It is conceivable that mobile units can be built for decontaminating a large area to a depth of one to several feet. The desorbed vapor can be collected by suction and treated.
Response:	Microwave heating is a desorption process and will be included under thermal desorption for direct and in-situ applications.
Comment 16: Page A-5-5 Section 5.1.3	Extracted vapors could also be treated by catalytic oxidation, or recovered by condensation or solvent absorption.
Response:	This comment is noted and will be incorporated.
Comment 17: Page A-5-8 Section 5.1.11	This section is redundant to section 5.1.4.
Response:	This comment is noted and the text will be changed accordingly.
Comment 18: Page A-5-13 Section 5.3.2.1.	Is microwave plasma really an in-situ process?
Response:	Microwave heating and microwave plasma are the same process.
Comment 19: Page A-5-13 Section 5.3.2.2.	Delete. Radio frequency heating is not an oxidation/ incineration process.
Response:	This comment is noted and the text will be changed accordingly.

<u>Comment 20</u>: Page A-5-14 Section 5.3.2.4	Is hot plasma really an in-situ process?
<u>Response</u>:	Theoretically hot plasma could be done in-situ, however, implementation may be difficult.
<u>Comment 21</u>: Page A-5-15	Add microwave desorbtion and radio frequency desorbtion.
<u>Response</u>:	This addition is appropriate and will be incorporated. Microwave desorbtion will be included under microwave heating.